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Environmental Protection Agency, Philadelphia, Pa Region III

Jul 77

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U.S. ENVIRONMENTAL PROTECTION AGENCY

EFFECTS OF OCEAN DUMPING ACTIVITY
MID-ATLANTIC BIGHT - 1976
INTERIM REPORT

July 1977

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MIDDLE ATLANTIC REGION-III 6th and Walnut Streets, Philadelphia, Pennsylvania 19106

EPA 903/9-77-029

EFFECTS OF OCEAN DUMPING ACTIVITY
MID-ATLANTIC BIGHT - 1976
INTERIM REPORT

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Annapolis, Maryland 21401

July 1977

Project Officer

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Philadelphia, Pennsylvania 19106

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Significantly high concentrations of metals present in the City of Philadelphia sewage sludge can be found on occasion at points in the sediments in and near the sludge release site. Several bands with high concentrations of metals, in association with high organic carbon, have been partially identified and have persisted for at least 14 months in and adjacent to the southern part of the site. Ambient concentrations of the metals in question have been derived by statistical comparisons over a 3 year period. Polychlorinated biphenyls (PCB's) were widely distributed in concentrations that may be inimical to marine organisms with indicated cyclical inputs, possibly from the coastal zone. Mortalities of the mahogany clam, Arctica islandica, were indicated at loci in and near the ocean dumping activity. Detailed bathymetry of the impacted area south of the site indicates geomorphic features may affect the aggregation of dumped materials. Statistically significant changes of the benthic infaunal communities are occurring in the impacted area south of the sewage sludge release site. Mollusks in the vicinity of the site appear to harbor bacteria of sanitary significance.

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Infauna

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The EPA Environmental Research Laboratory, Narragansett, Rhode Island, has provided personnel for cruises and initiated special studies. The EPA Wheeling Field Office assisted in these cruises. Chris Ostrom, Maryland Department of Natural Resources, and Robert Davis, EPA Region III, were especially effective participants on cruises. Capt. James Verber, Cdrs. Adams and Gaines, U.S. Food and Drug Administration, Davisville, Rhode Island, provided expertise in bacteriological analyses and sampling.

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It is difficult to completely list all persons to whom grateful acknowledgements are due, and many others not listed have materially contributed to the program.

CONCLUSIONS

1. Significantly high concentrations of metals known to be present in City of Philadelphia sewage sludge can be found on occasion at points in the sediments in and near the sludge release site. Several bands with consistently high concentrations of metals, in association with high organic carbon, have been partially identified and have persisted for at least fourteen months in and adjacent to the southern part of the sludge release site.

2. Ambient concentrations of the metals in question have been derived by statistical comparisons over a three year period.

3. Polychlorinated biphenyls (PCB's) were widely distributed in concentrations that may be inimical to marine organisms. The time distribution indicated cyclical inputs, possibly from the coastal zone. Localized areas of high impact, associated with other parameters from sewage sludge, have been identified.

4. Mortalities of the mahogany clam, *Arctica islandica*, were indicated at loci in and near the ocean dumping activity.

5. The large areas of anoxic waters off New Jersey in summer 1976 apparently did not extend into this study area, judging from relative mortalities of macrobenthic fauna.

6. Detailed bathymetry of the persistently impacted area south of the sludge release site indicates gentle geomorphic features may affect the aggregation of dumped materials.

7. Statistically significant changes of the benthic infaunal communities are occurring in the impacted area south of the sewage sludge release site.

8. A preliminary indication of diseased macrofauna associated with the impacted area was found in February 1977.

9. Molluscan shellfish in the vicinity of the sewage sludge site appear to harbor bacteria of sanitary significance.

INTRODUCTION

The ecological effects of a populous technological society on the environment became increasingly pronounced and obvious in the past two decades. Legislation in the early 1970's was passed to recognize and control deleterious effects on the environment.

The Marine Protection, Research and Sanctuaries Act of 1972 (PL 92-532, the "ocean dumping act") was passed to regulate ocean dumping activities. One requirement of this legislation is a knowledge of the ecological effects of ocean dumping activities as a condition for the issuance of permits.

EPA Region III, in May 1973, initiated a field monitoring program on two active dumpsites located approximately 40 miles east of the Delaware-Maryland seacoast. A program was designed with emphasis on the longer term, more persistent effects, especially on the benthic environment, as contrasted to the more transient effects in the water column. EPA research laboratories in Narragansett, Rhode Island, and Corvallis, Oregon, were instrumental in the initial efforts. Many other persons and institutions, as noted in the acknowledgements, have participated.

The site locations of the area of study are shown in Figure 1. Station locations are shown in Figures 2 and 3.

Several reports have been issued by EPA on the earlier phases of this program (Palmer and Lear, 1973; Lear, Smith and O'Malley, 1974;

-/

Lear, 1974; Lear and Pesch, 1975) as well as summaries of program results at ocean dumping permit hearings, which information is available at EPA Region III, Philadelphia, Pa.

Several reports related to these studies have recently become available. Forns (1977) has described the phytoplankton and zooplankton findings from these cruises. Palmer et al. (1976) have described the results of recording current meter observations and inferred bedload transport in this area. Demenkow and Wiekramaratne (1976) have developed a mathematical model of dispersal and settling of sewage sludge into this environment. Klemas et al. (1976) have reported on circulation studies in this area, conducted with radar-tracked drogues. Marine Research, Inc. (1975, 1975, 1976, 1976) has produced a series of reports, under contract with EPA Region III, with detailed identification, enumeration and relationships of the benthic infauna of this area. Interstate Electronics Corp. (1977) under contract to EPA, has compiled an extensive and exhaustive data bank pertinent to this area, from many sources.

This report will be primarily concerned with results of the most recent four cruises (Operation Touchstone, December 1975; Operation Pickup, June 1976; Operation Hotspot, August 1976; Operation Mogul, February 1977) covering the span of time from winter 1975 to date.

In the past year several noteworthy events have been noted on the continental shelf of the Mid-Atlantic Bight:

1. An insurgence of interest on the Mid-Atlantic continental shelf as an ecosystem was engendered by the prospects of oil production.

The results of the necessary environmental studies are beginning to become available, with substantially increased information expected in the next year or so.

2. There was a cessation of dumping of industrial acid wastes at the nearby site in February 1977.

3. The track of Hurricane Belle indicated the eye of this small, fast moving storm passed approximately over the dumpsite in August 1976.

4. A major area of dissolved oxygen depletion was noted, involving thousands of square miles off the New Jersey coast.

5. The winter of 1977 was atypically cold, and some measured parameters indicate the effects of this weather could be found on the continental shelf.

The data presented herein do not represent all of the studies in this ocean dumping monitoring program. Many samples remain archived awaiting analysis, and many other data have not yet been plotted and analyzed. This report summarizes some of the more salient aspects of these investigations, primarily during the calendar year 1976. This report is, in essence, a progress report. Field investigations and summarization of data are continuing.

FIGURE 1

AREA OF STUDY

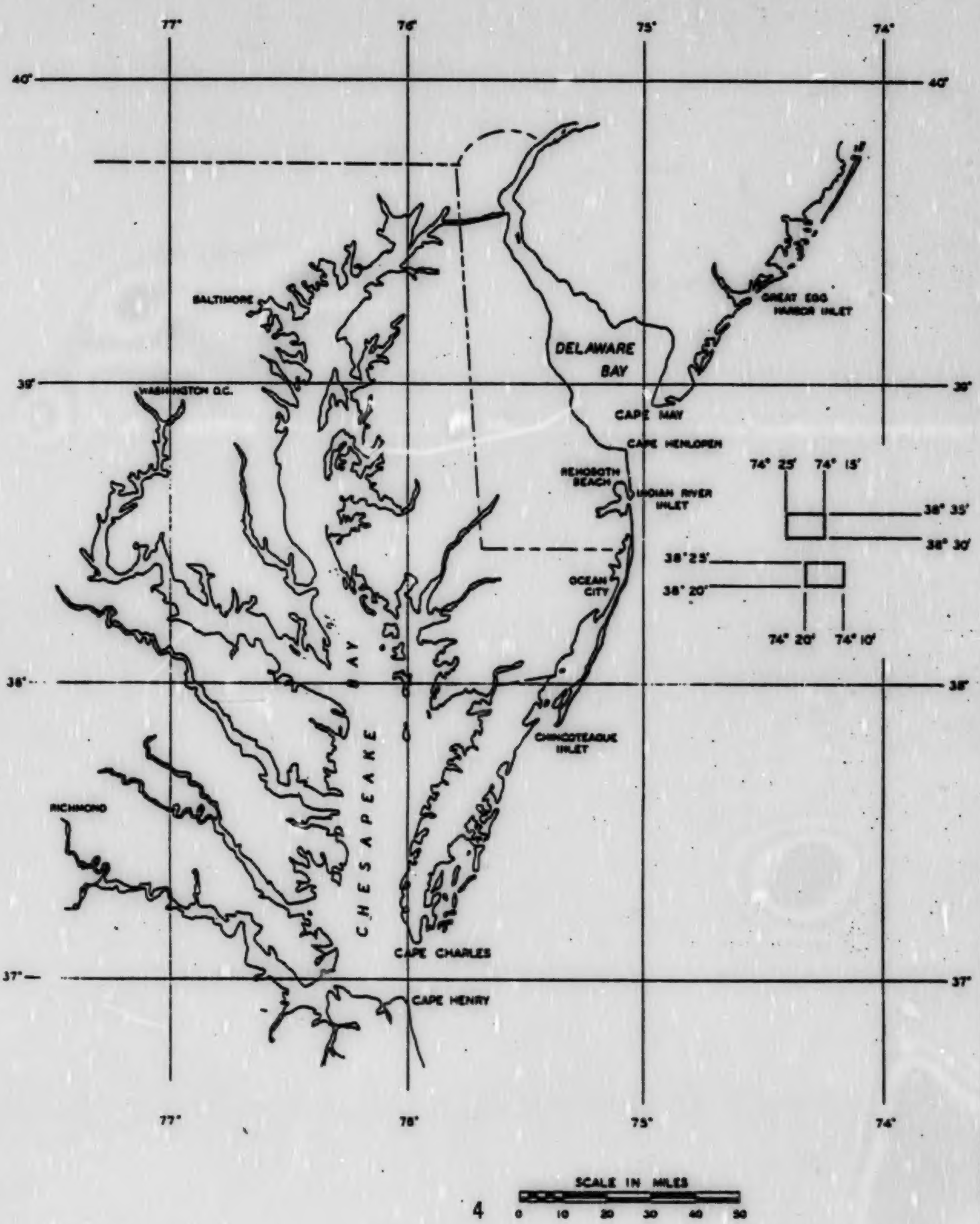
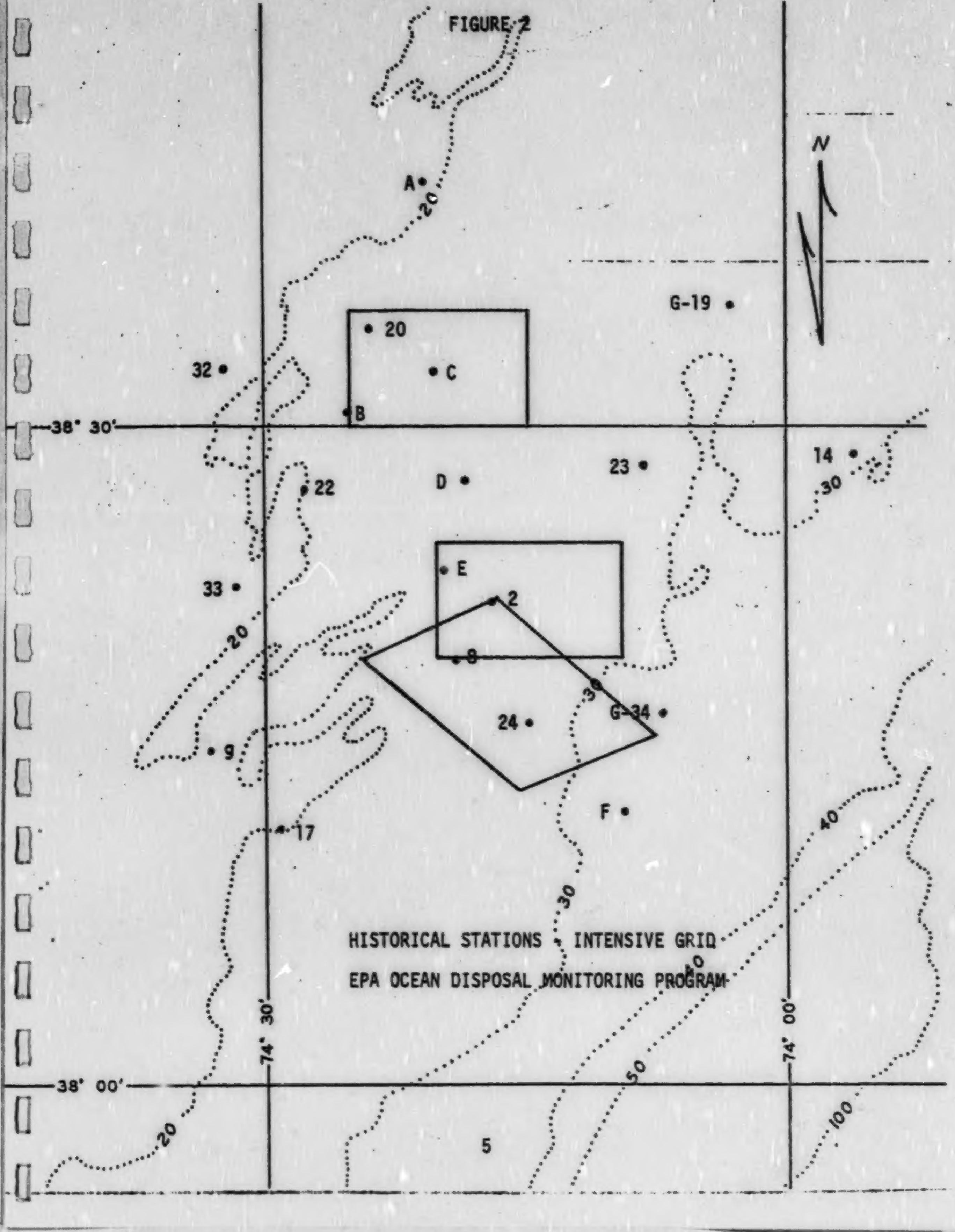

77°
76°
75°
74°
40°
39°
38°
37°
BALTIMORE
WASHINGTON D.C.
RICHMOND
DELAWARE BAY
GREAT EGG HARBOR INLET
CAPE MAY
CAPE HENLOPEN
REHOBOTH BEACH
INDIAN RIVER INLET
OCEAN CITY
CHINCOTEAGUE INLET
CHESAPEAKE BAY
CAPE CHARLES
CAPE HENRY
74° 25'
74° 15'
38° 35'
38° 30'
38° 25'
38° 20'
74° 20'
74° 10'
SCALE IN MILES
0
10
20
30
40
50

FIGURE 2



N
A
20
G-19
20
32
C
B
38° 30'
14
23
30
D
22
E
33
2
20
8
30
G-34
24
9
F
17
30
40
40
74° 30'
74° 00'
38° 00'
50
20
100

HISTORICAL STATIONS - INTENSIVE GRID

EPA OCEAN DISPOSAL MONITORING PROGRAM

METHODOLOGY

Sampling on all three cruises was from the USCGC ALERT, a 210' Cutter based at Cape May, New Jersey and modified for oceanographic operations. Navigation was done with the Coast Guard "Sealad" modification of Loran C, with digital readout in yards from preassigned location. Depth recordings were made on the ship's EDO recording fathometer.

Hydrographic determinations were made using a mechanical BT for temperature and depth and/or conductivities, temperature and salinity by a Beckman RS-5 field induction salinometer. Salinity values were verified in the laboratory with random grab samples run on a Beckman RS-7C bench top salinometer.

Water samples for bacteriological analyses were taken by a Niskin hinge sampler with sterile PE bags.

Bottom grabs at historical monitoring stations were made using a Shipek sediment sampler. Four replicates were taken at each station. The first grab was sacrificed for bacteriological subsamples and organohalogens. Sediment for organohalogen determination was put in hexane washed quart jars with teflon lids and stowed for laboratory analysis.

Three grabs were sampled for metals, sediment size, total organic carbon,and the remainder for infauna.

A small polyethylene cup was filled with sediment for metals analyses, a small glass vial for TOC. These were then quick frozen on dry ice. A 6 oz. whirlpak was partially filled for sediment size and stowed.

The remainder of the sample was placed in a gallon polyethylene jar, preserved with 10% buffered formalin and stowed for subsequent infauna sorting and identification.

At stations in the intensive grid one Smith-McIntyre grab was made at each station and three replicates for each parameter sampled from the single grab.

Macrofauna was collected using a Fall River rocking chair dredge.

Laboratory methods can be found in Palmer and Lear (1973), Lear and Pesch (1975) and Marine Research, Inc. (1975).

REGIONAL MONITORING PROGRAM

HYDROGRAPHY

Station locations and the planar depth presentation of hydrographic data are shown in Figure 3.

The distribution of temperature in December 1975 is shown in Figure 4, with cooler surface waters intruding into the area from the northwest. No vertical stratification was evident.

The distribution of salinity (Figure 5) indicates the input of fresher waters from the coast at this season.

The distribution of temperature in June 1976, Operation Pickup, shows the typical thermocline development and orientation of isotherms approximating the isobaths (Figure 6). Warmer surface waters were evident inshore. Temperatures below the thermocline were typical for this season.

Salinities showed very little variation laterally or with depth, and were generally slightly greater than 32 °/₀₀ (Figure 7). One station at the southeast portion of the study area showed anomalously high values.

In August 1976 the waters were at midsummer temperatures, with thermocline developed, and surface waters with no distributional patterns (Figure 8). The thermocline was 16 to 20 meters, as usually found.

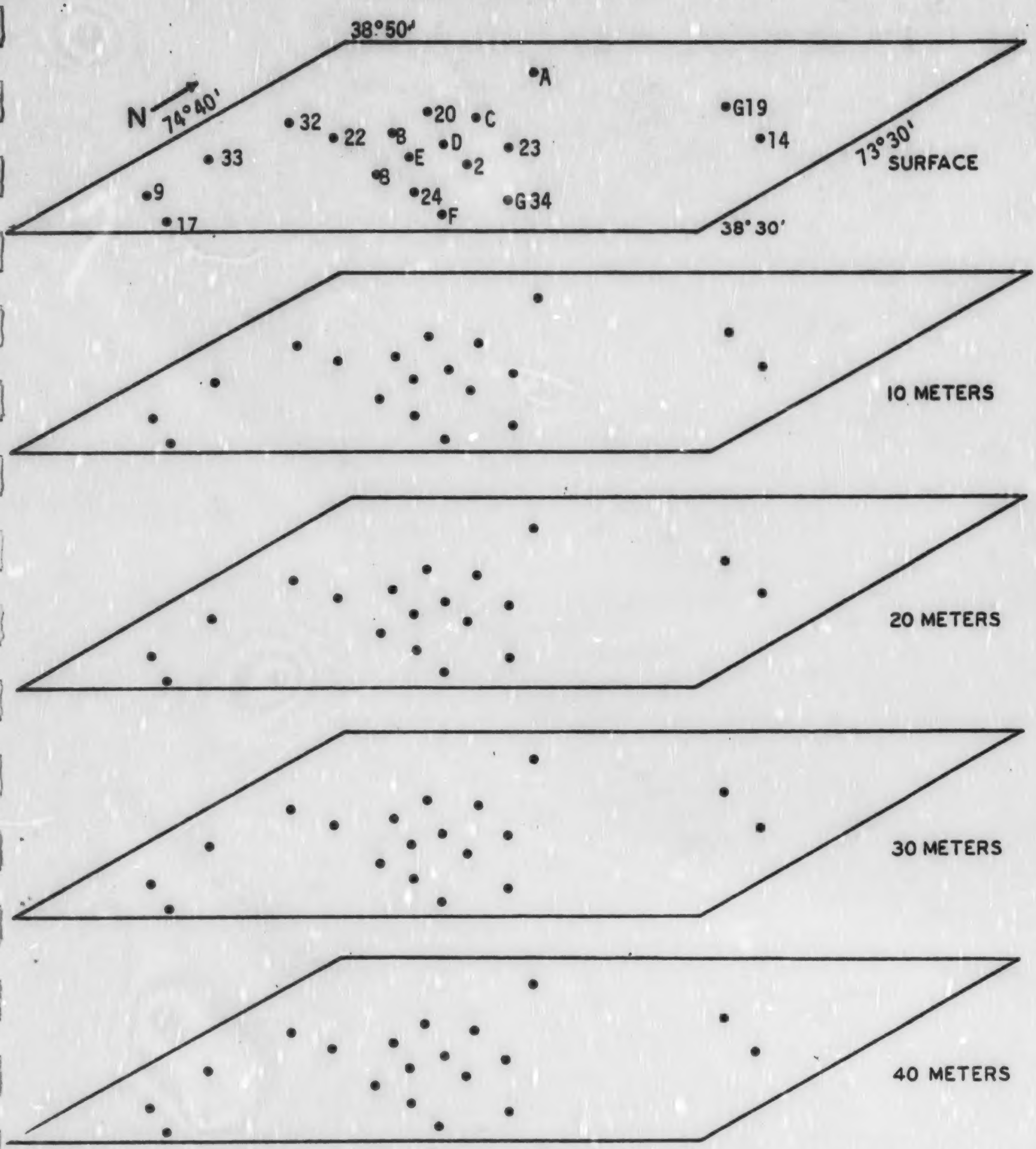
The winter of 1977 was atypically cold in the eastern United States. This was reflected on the continental shelf with water temperatures of less than 3°C extending out on the shelf. The warmest waters were again found at the southeast corner of the study area (Figure 9).

The distribution of salinity showed the typically higher values characteristic of winter conditions. A tongue of slightly fresher water was indicated extending from the shore in center of the study area. No pronounced stratification with depth was noted (Figure 10).

These observations indicate that in the time span noted, hydrographic features were those characteristic of this area (Bumpus, 1974). The presence of the major Delaware estuary was noted with the tongue of fresher surface water penetrating the study area. The winter of 1977 was atypically cold, and the inshore waters were especially affected by the meteorological phenomenon.

FIGURE 3

HISTORICAL STATION LOCATIONS



38°50'
N
74°40'
A
G19
20
C
32
22
8
D
23
14
33
E
2
73°30'
SURFACE
8
9
24
G34
17
F
38°30'
10 METERS
20 METERS
30 METERS
40 METERS

FIGURE 4
DISTRIBUTION OF TEMPERATURE
Operation Touchstone - Cruise 75-VI
December 1975

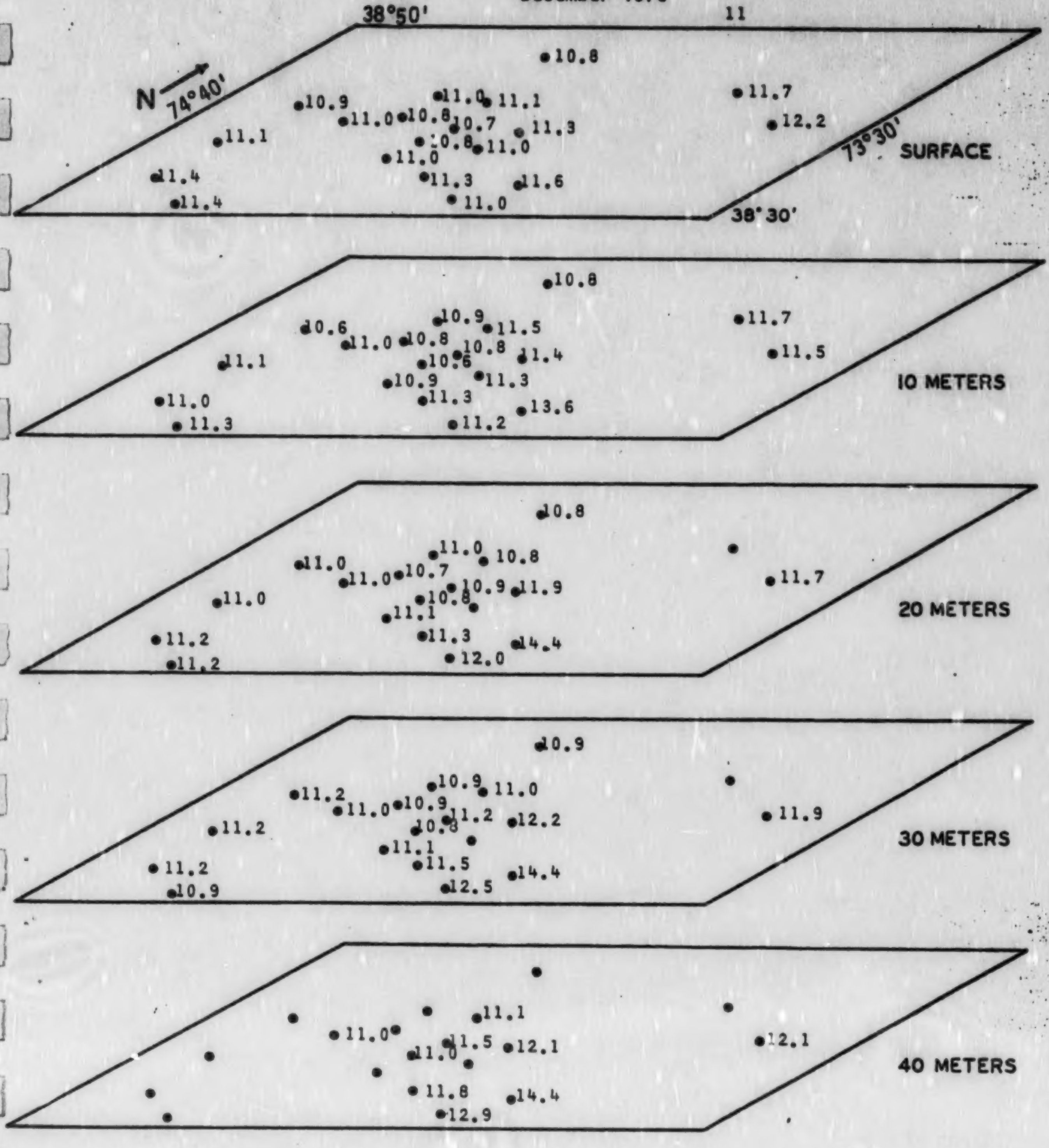


FIGURE 5
DISTRIBUTION OF SALINITY
Operation Touchstone - Cruise 75-VI
December 1975

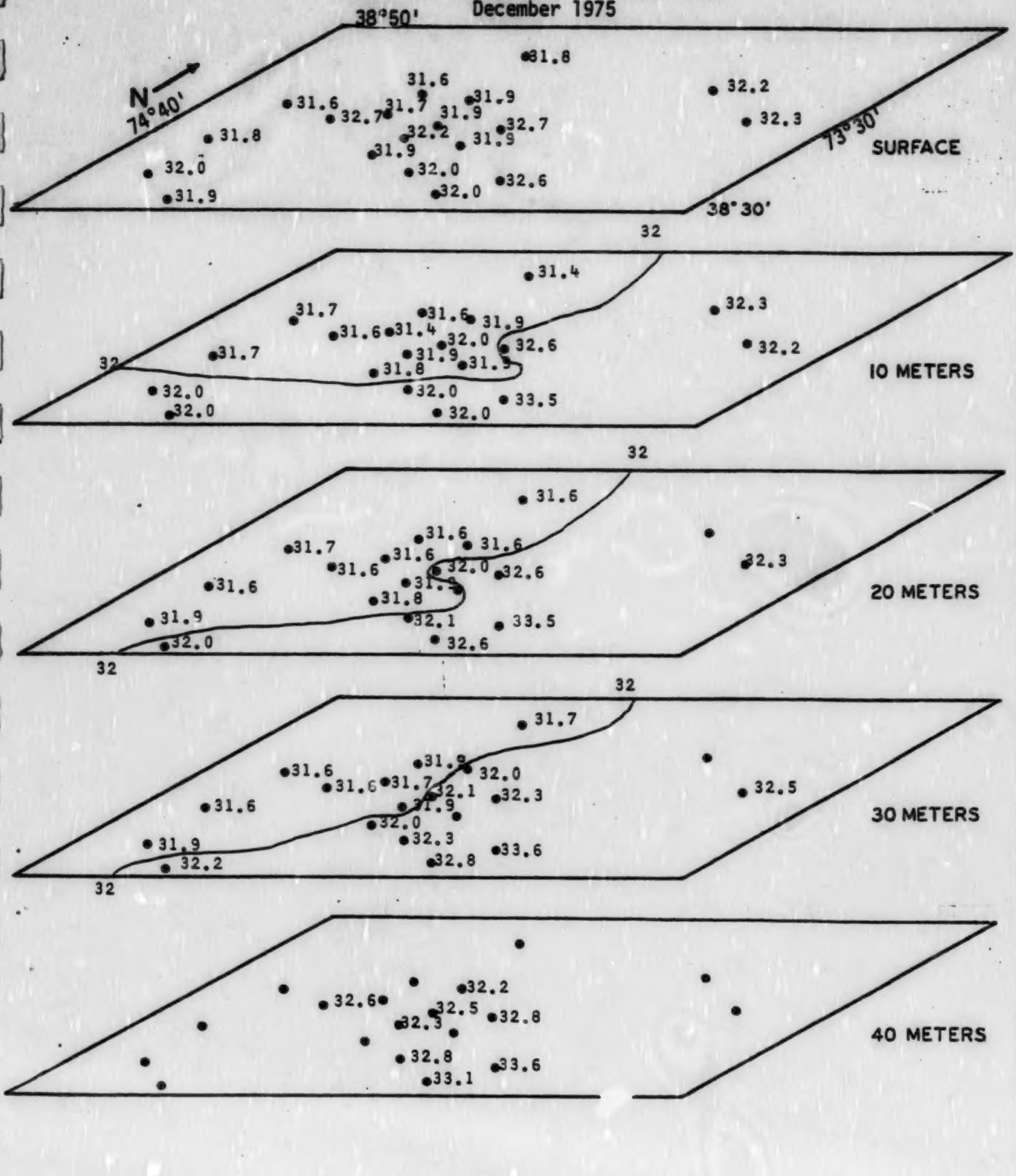

38°50'
N
74°40'
73°30'
38°30'
SURFACE
31.8
31.6
31.9
31.6
32.7
31.7
31.9
32.2
32.3
31.8
32.2
32.7
31.9
31.9
32.0
32.0
32.6
31.9
32.0
10 METERS
32
31.4
31.7
31.6
31.9
31.6
31.4
32.0
32.3
32.6
32.2
31.7
31.9
31.8
31.9
32.0
32.0
33.5
32.0
32.0
20 METERS
32
31.6
31.6
31.7
31.6
31.6
31.6
32.0
32.6
32.3
31.6
31.8
31.9
32.1
33.5
32.0
32.6
30 METERS
32
31.7
31.9
32.0
31.6
31.6
31.7
32.1
32.3
32.5
31.6
31.9
32.0
31.9
32.3
33.6
32.2
32.8
40 METERS
32.2
32.6
32.5
32.8
32.3
32.8
33.6
33.1

FIGURE 6
DISTRIBUTION OF TEMPERATURE
Operation Pickup - Cruise 76-I
June 1976

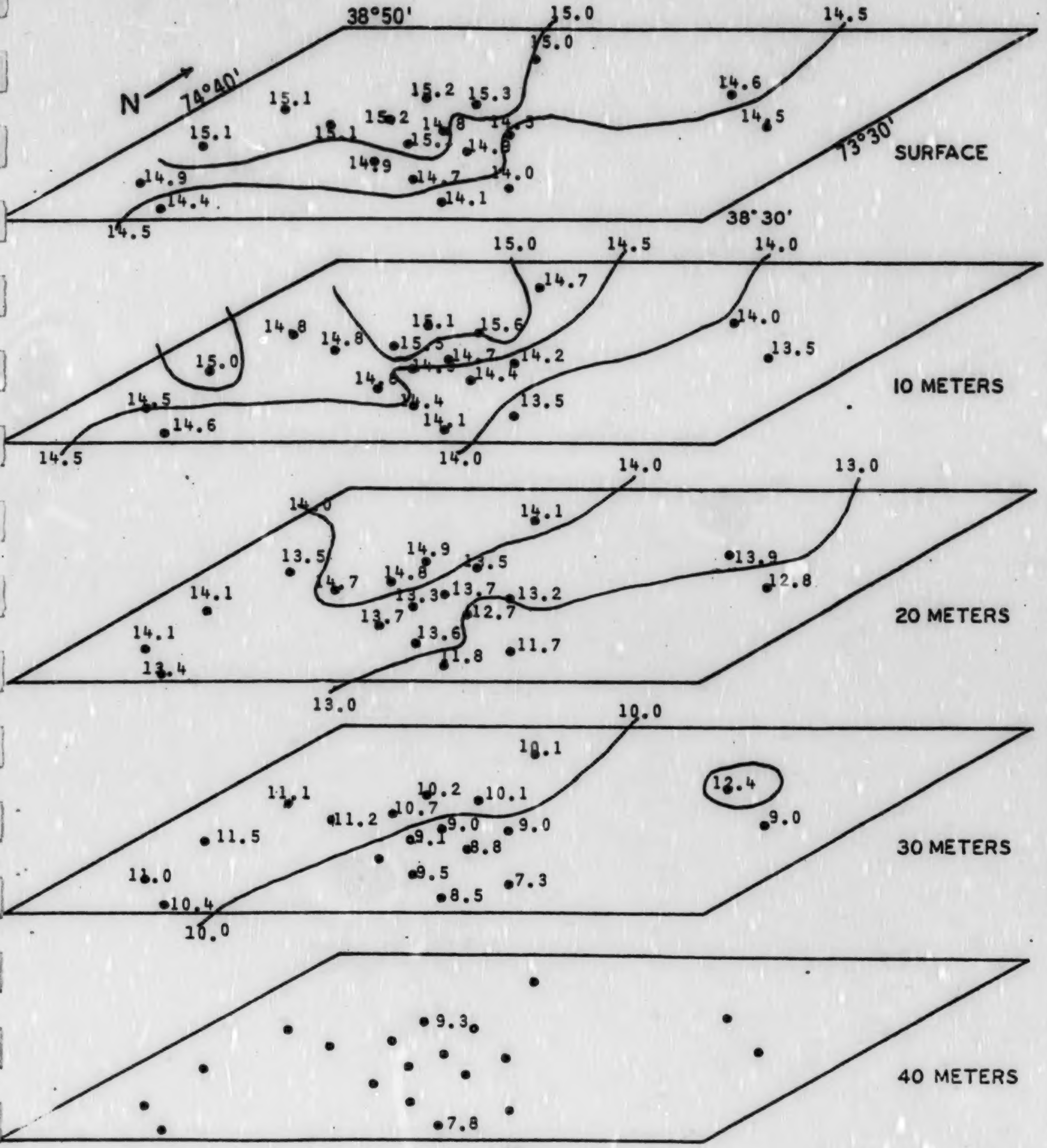

38°50'
74°40'
N
73°30'
38°30'
SURFACE
15.0
14.5
15.1
15.2
15.3
14.6
14.8
14.3
14.9
14.7
14.0
14.4
14.1
10 METERS
15.6
13.5
14.2
20 METERS
13.0
13.9
12.8
13.3
13.7
13.2
13.6
12.7
11.8
11.7
30 METERS
10.0
10.1
12.4
11.1
10.2
10.7
11.2
9.0
11.5
9.1
8.8
9.5
7.3
11.0
10.4
8.5
40 METERS
9.3
7.8

FIGURE 7
DISTRIBUTION OF SALINITY
Operation Pickup - Cruise 76-I
June 1976

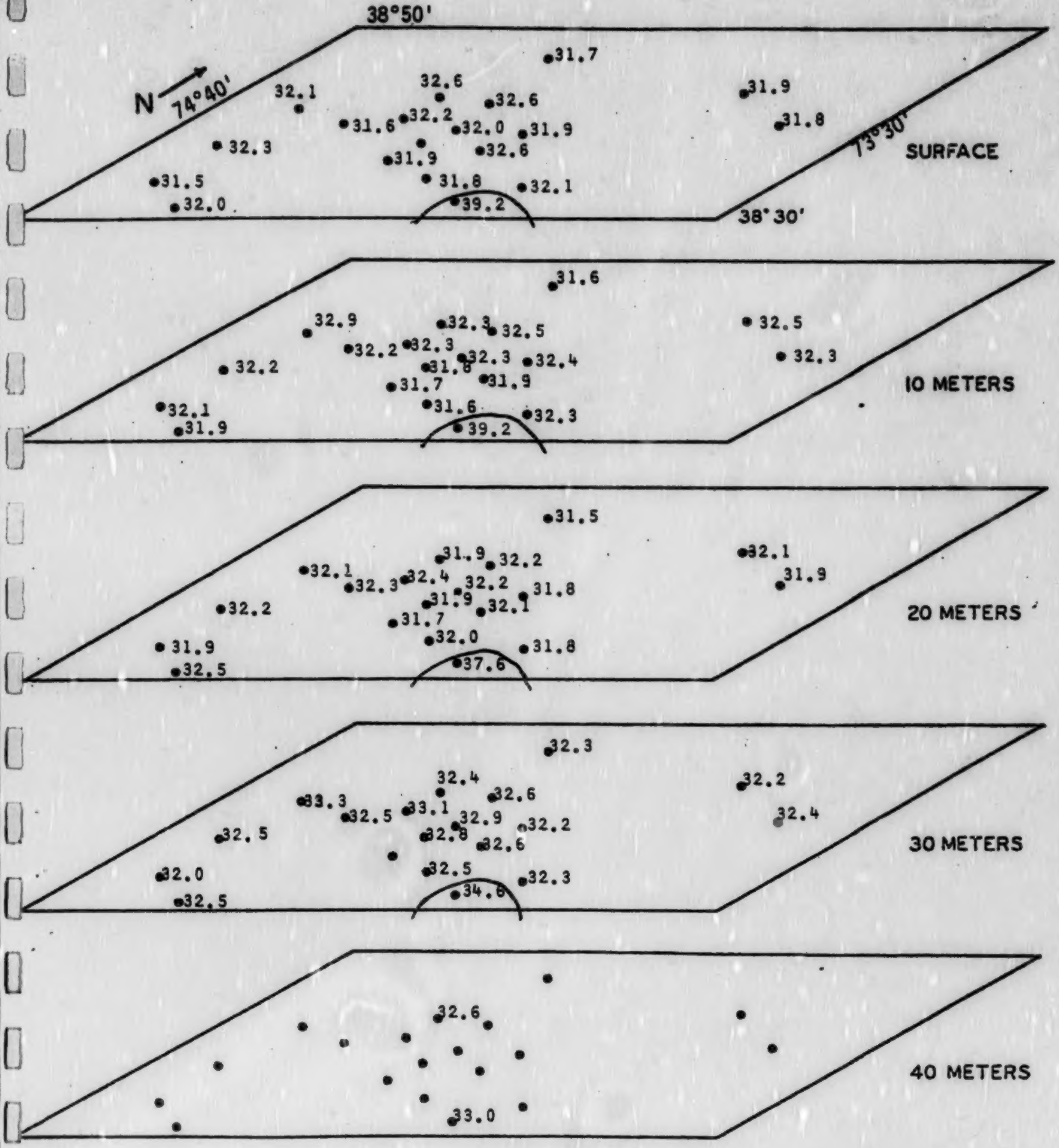

38°50'
N
74°40'
73°30'
38°30'
SURFACE
31.7
32.1
32.6
32.6
31.9
31.6
32.2
32.0
31.9
31.8
32.3
32.6
31.9
31.5
31.8
32.1
32.0
39.2
10 METERS
31.6
32.9
32.3
32.5
32.5
32.2
32.3
32.3
32.4
32.3
32.2
31.8
31.7
31.9
32.1
31.6
32.3
31.9
39.2
20 METERS
31.5
31.9
32.2
32.1
32.1
32.4
32.2
31.8
31.9
32.3
31.9
32.2
32.1
31.7
32.0
31.9
31.8
32.5
37.6
30 METERS
32.3
32.4
32.6
32.2
33.3
33.1
32.5
32.9
32.2
32.4
32.5
32.8
32.6
32.0
32.5
32.3
32.5
34.6
40 METERS
32.6
33.0

FIGURE 8
DISTRIBUTION OF TEMPERATURE
Operation Hotspot - Cruise 76-I
August 1976
(BT Observations)

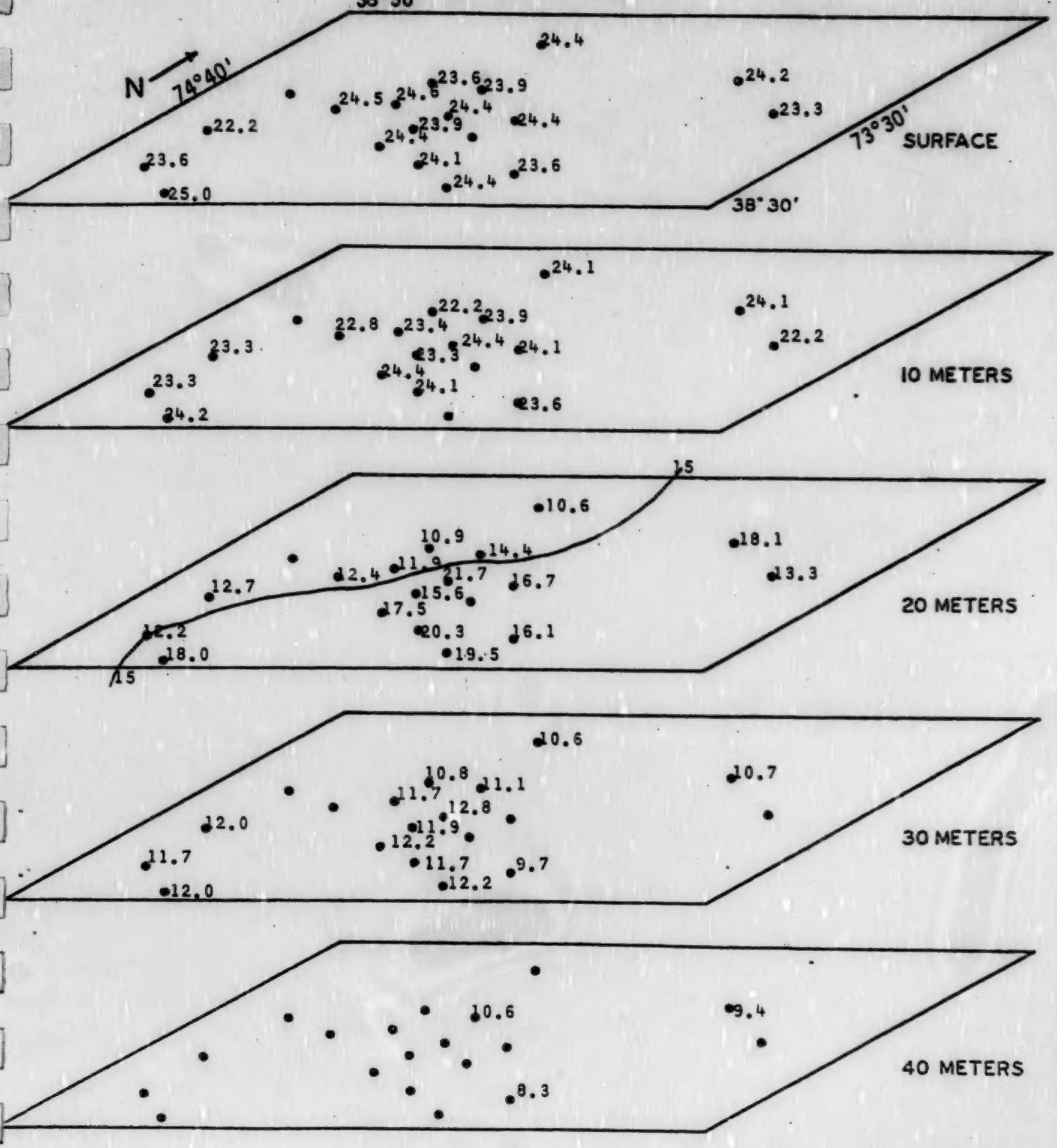

38°50'
N
74°40'
24.4
23.6
23.9
24.2
24.5
24.6
24.4
24.4
23.3
22.2
23.9
24.4
73°30'
SURFACE
23.6
24.1
23.6
25.0
24.4
38°30'
24.1
22.2
23.9
24.1
22.8
23.4
24.4
24.1
22.2
23.3
23.3
24.4
10 METERS
23.3
24.1
24.2
23.6
15
10.6
10.9
14.4
18.1
12.4
11.9
21.7
16.7
13.3
12.7
15.6
17.5
20 METERS
12.2
20.3
16.1
18.0
19.5
15
10.6
10.8
11.1
10.7
11.7
12.8
12.0
11.9
12.2
30 METERS
11.7
11.7
9.7
12.0
12.2
10.6
9.4
40 METERS
8.3

FIGURE 9
DISTRIBUTION OF TEMPERATURE
Operation Mogul - Cruise 77-I
February 1977

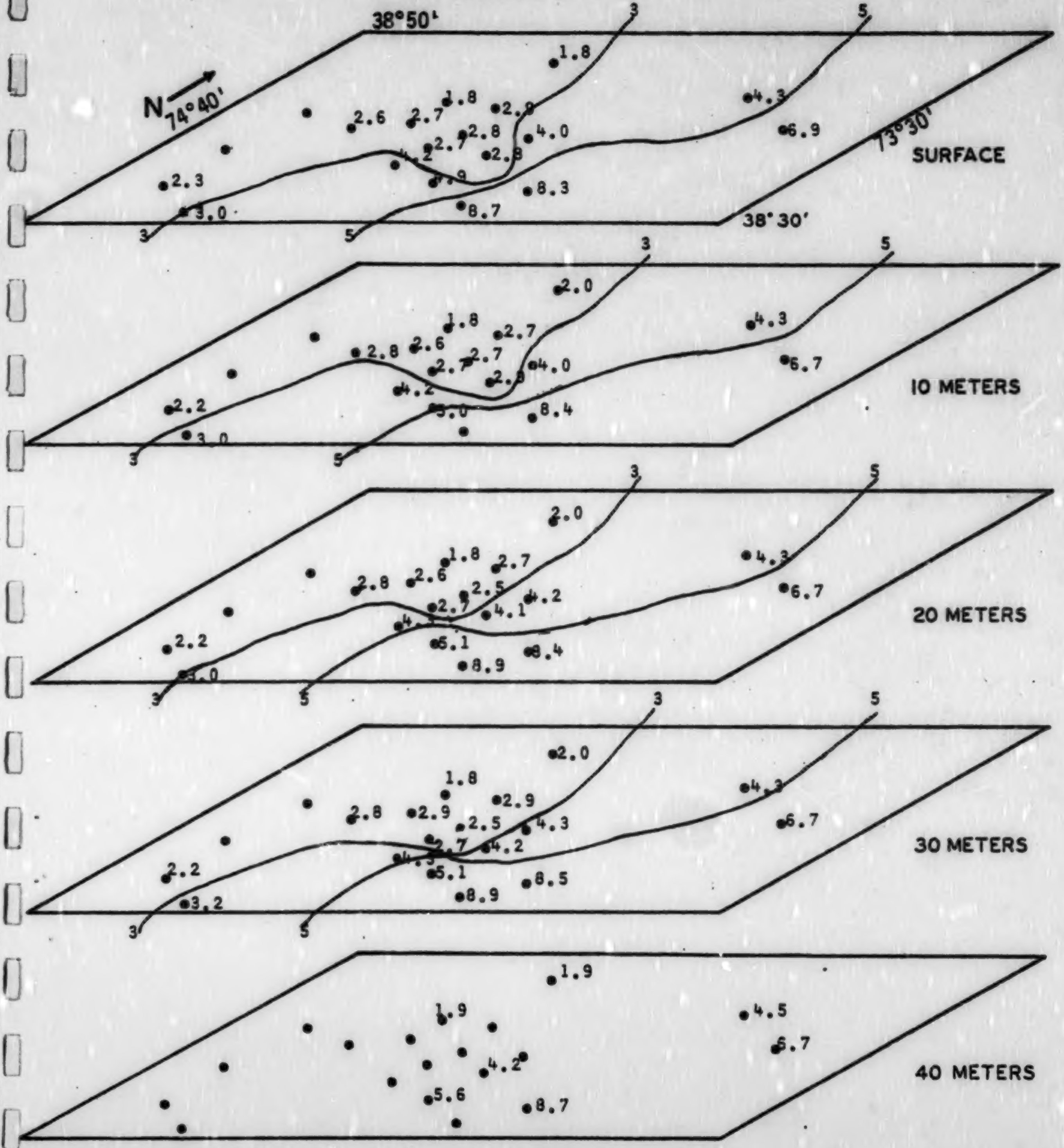
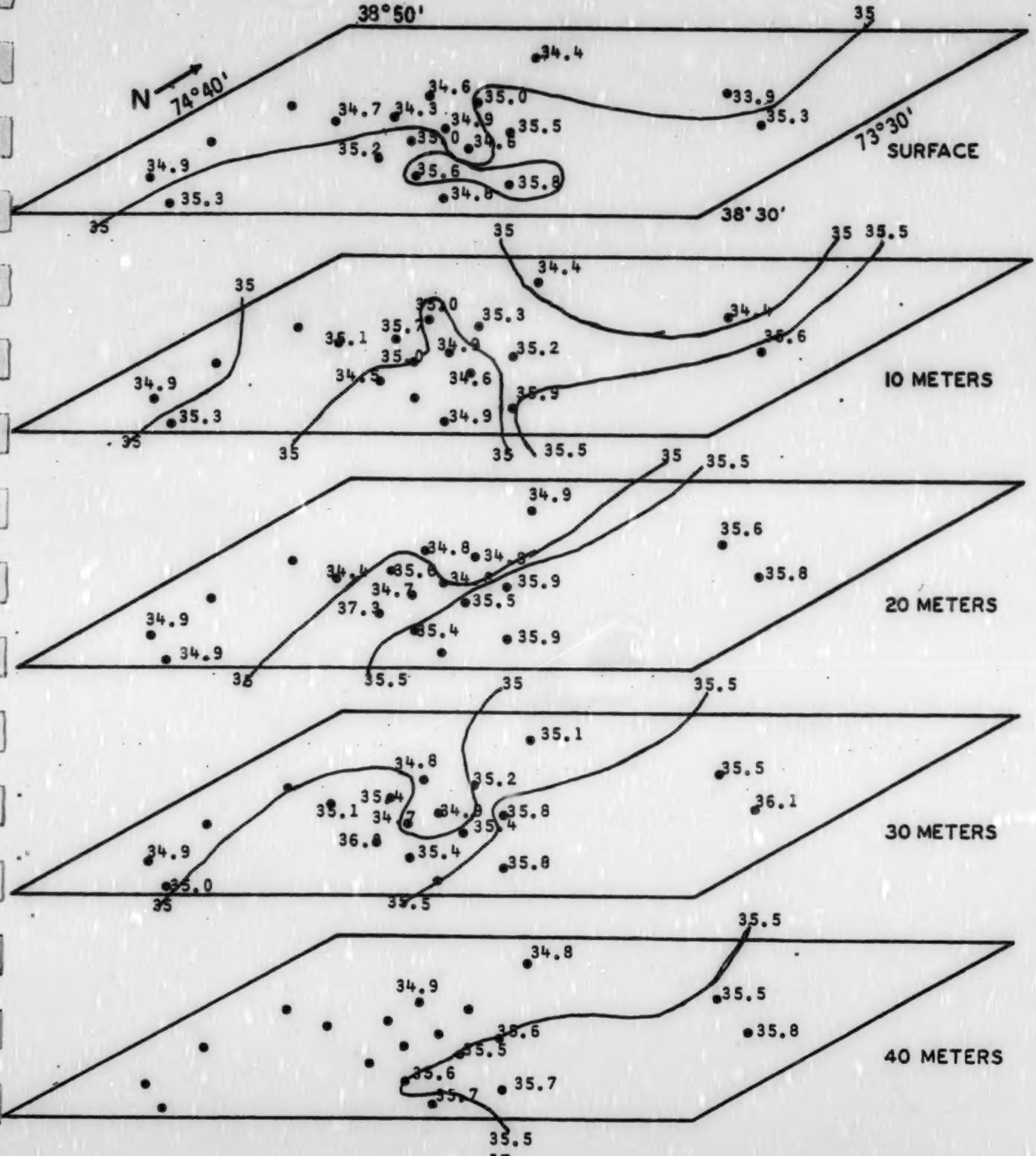

38°50'
N
74°40'
73°30'
38°30'
3
5
1.8
2.6
2.7
2.9
2.8
4.0
2.7
4.2
2.8
2.3
3.0
7.9
8.3
8.7
4.3
6.9
SURFACE
2.0
1.8
2.7
2.8
2.6
2.7
2.7
4.0
2.9
4.2
2.2
3.0
3.0
8.4
4.3
6.7
10 METERS
2.0
1.8
2.7
2.8
2.6
2.5
4.2
2.7
4.1
4.3
5.1
8.4
2.2
3.0
8.9
4.3
6.7
20 METERS
2.0
1.8
2.9
2.8
2.9
2.5
4.3
2.7
4.2
4.3
5.1
8.5
2.2
3.2
8.9
4.3
6.7
30 METERS
1.9
1.9
4.5
6.7
4.2
5.6
8.7
40 METERS

FIGURE 10
DISTRIBUTION OF SALINITY
Operation Mogul - Cruise 77-I
February 1977



REGIONAL MONITORING PROGRAM

HISTORICAL STATIONS - METALS IN SEDIMENTS

A major component of the monitoring of this continental shelf environment was the determination of the maximum temporal and spatial extent of measurable inputs of pollutants on the sea floor. The routine monitoring station grid (historical) stations, covering approximately 40 x 50 mile (2000 mi^2) area, was designed to determine the ambient levels of parameters, to identify areas impacted, to estimate the extent of translocation of deposited materials, and to determine other possible inputs to the area.

A series of tables and figures (Tables 1-7 and Figures 11-28) show the distribution of metals in sediments on cruises Touchstone (December 1975), Hotspot (August 1976) and Mogul (February 1977). The tables display results of analysis by Duncan's new multiple range test, with three sample replications (Steele and Torrie,1960). Lines along the ranked columns of concentrations include sets statistically related at the 0.05 probability level.

Considering the data for this period, Stations A and D showed no elevations of concentrations of any metal on any of the three cruises. Station A, the northernmost of the monitoring stations, was probably outside the influence of dumping activity, with known circulation patterns primarily to the northeast and southwest from the release sites.

Station D, between the acid waste site and the sludge site, is located on one of two fairly prominent small elevations known to the fishermen as the "sausages". As indicated in the discussions on bathymetry, such elevations are probably more readily swept clean of such materials as may be deposited thereon.

The stations with most evidence of increased concentrations of metals were 9, 20, 22, G-19, G-34, C, and F. Stations 9, 22, G-34 and F were generally south of the dumping activity, in the path of known net water movement. Stations C and 20 were on the western sector. of the industrial acid waste release site. Station G-19, first occupied in June 1975, has consistently shown evidence of a catastrophic impaction of metals and mortalities of mahogany clams.

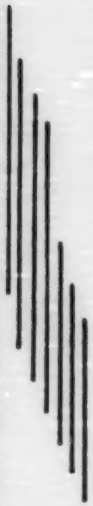
The metals in sediments at these stations indicate intermittent residence of high concentrations of metals on the benthos at sites over a wide area, most commonly to the westerly and southerly directions from the release sites. Certain areas, such as the aforementioned Stations C, G-19, 20, 9, G-34, and F showed consistently higher concentrations of metals than other stations. This may be as a result of a local more permanent residence of materials or possibly multiple input events.

TABLE 1

METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Historical Stations

TOC

Station	Mean
B	417
22	443
33	450
D	477
32	500
A	633
8	663
23	682
17	693
E	773
24	902
2	915
9	935
14	993
F	1190
G-34	1280
G-19	1340
C	2357

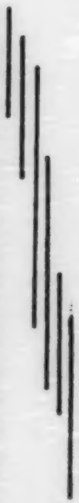


ANOVA

	df	sos	ms	F**
Between	17	11063731	650808	12.31
Within	33	1744367	52859	
Total	50	12808098		

IRON

Station	Mean
E	657
D	808
9	1070
17	1084
22	1164
A	1168
32	1296
14	1302
23	1338
8	1394
33	1458
2	1695
24	1773
B	1834
F	1958
G-19	1958
G-34	2078
C	2615

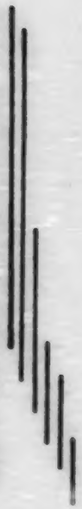


ANOVA

	df	sos	ms	F**
Between	17	13726350	807432	14.1
Within	36	2057409	57150	
Total	53	15783759		

Nickel

Station	Mean
D	0.28
8	0.66
32	0.67
B	0.68
E	0.73
17	0.82
24	0.85
9	0.94
14	1.22
2	1.24
23	1.26
A	1.28
F	1.56
G-34	2.37
G-19	2.57
22	2.88
C	3.77



ANOVA

	df	sos	ms	F**
Between	17	45.52	2.68	6.98
Within	36	13.81	0.38	
Total	53	59.33		

TABLE 2

METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Historical Stations

Pb

Station	Mean
32	1.20
E	1.33
D	1.87
9	2.12
A	2.17
F	2.46
B	2.77
33	2.89
14	3.11
23	3.67
8	3.68
2	3.89
17	4.08
24	4.16
G-19	4.20
C	4.31
G-34	4.51
22	5.95

ANOVA

	df	sos	ms	F
Between	17	78.50	4.62	2.11**
Within	36	78.83	2.19	
Total	53	157.33		

Cr

Station	Mean
A	1.84
D	2.18
33	2.37
E	2.47
8	2.66
9	2.99
17	3.01
F	3.17
32	3.27
B	3.28
2	3.41
22	3.58
G-34	3.60
G-19	3.84
24	3.87
23	3.91
C	4.56
14	5.38

ANOVA

	df	sos	ms	F
Between	17	39.57	2.33	1.73**
Within	36	48.36	1.34	
Total	53	87.93		

Cu

Station	Mean
22	<0.10
D	.12
14	.15
9	.17
24	.18
17	.18
B	.18
A	.21
23	.25
E	.28
33	.30
8	.32
F	.34
32	.41
2	.79
G-34	.83
C	1.13
G-19	1.25

ANOVA

	df	sos	ms	F
Between	17	6.36	0.37	4.80**
Within	36	2.80	0.078	
Total	53	9.17		

TABLE 3

METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Historical Stations

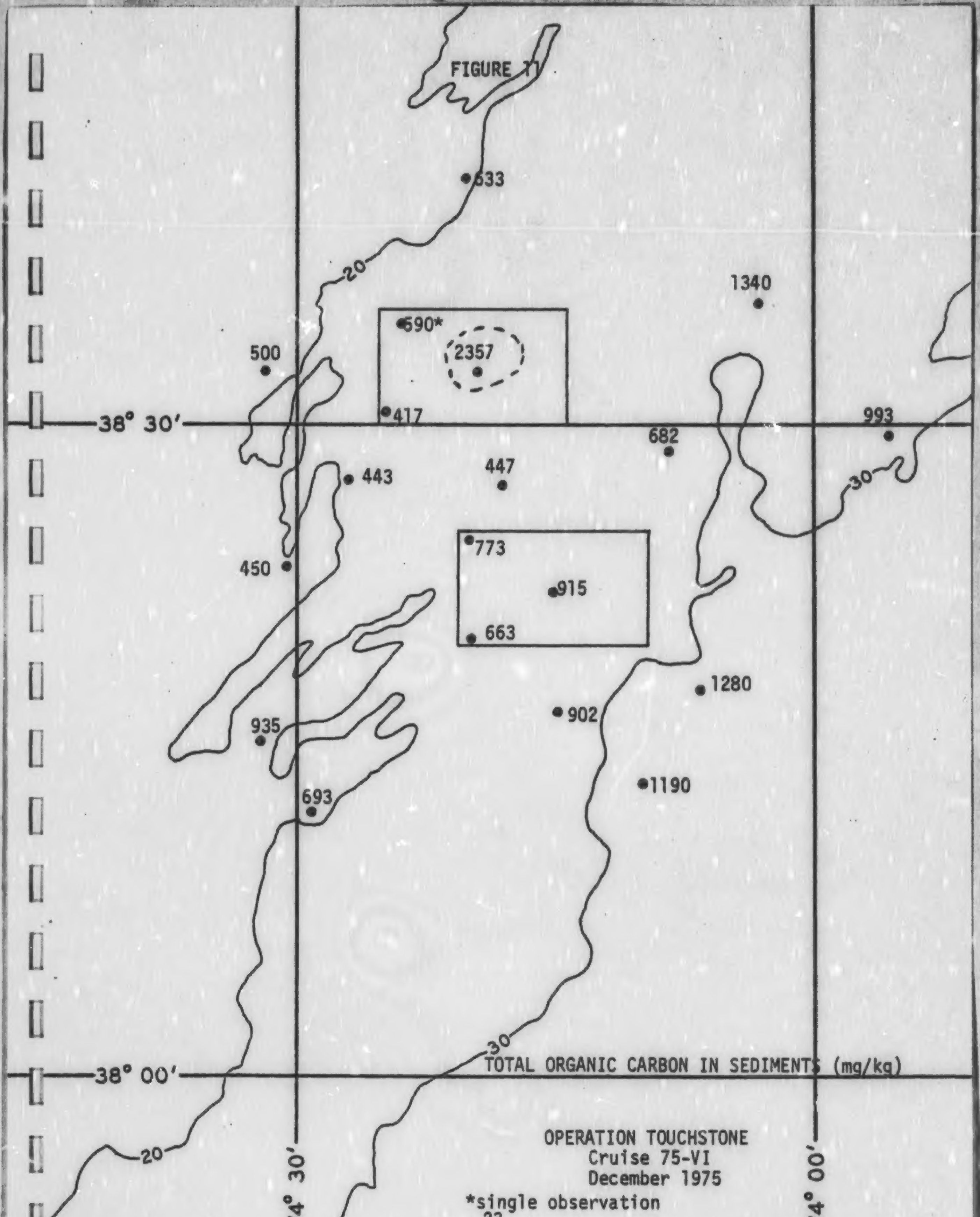
Zn

Station	Mean
D	1.96
8	2.70
33	2.80
E	2.92
17	2.94
24	2.98
22	3.09
9	3.16
14	3.56
23	3.64
A	4.01
32	4.29
B	4.31
2	5.57
G-19	6.13
G-34	6.41
F	6.92
C	7.80

ANOVA

	df	sos	ms	F
Between	17	131.28	7.72	5.48**
Within	36	50.73	1.41	
Total	53	182.01		

FIGURE 11

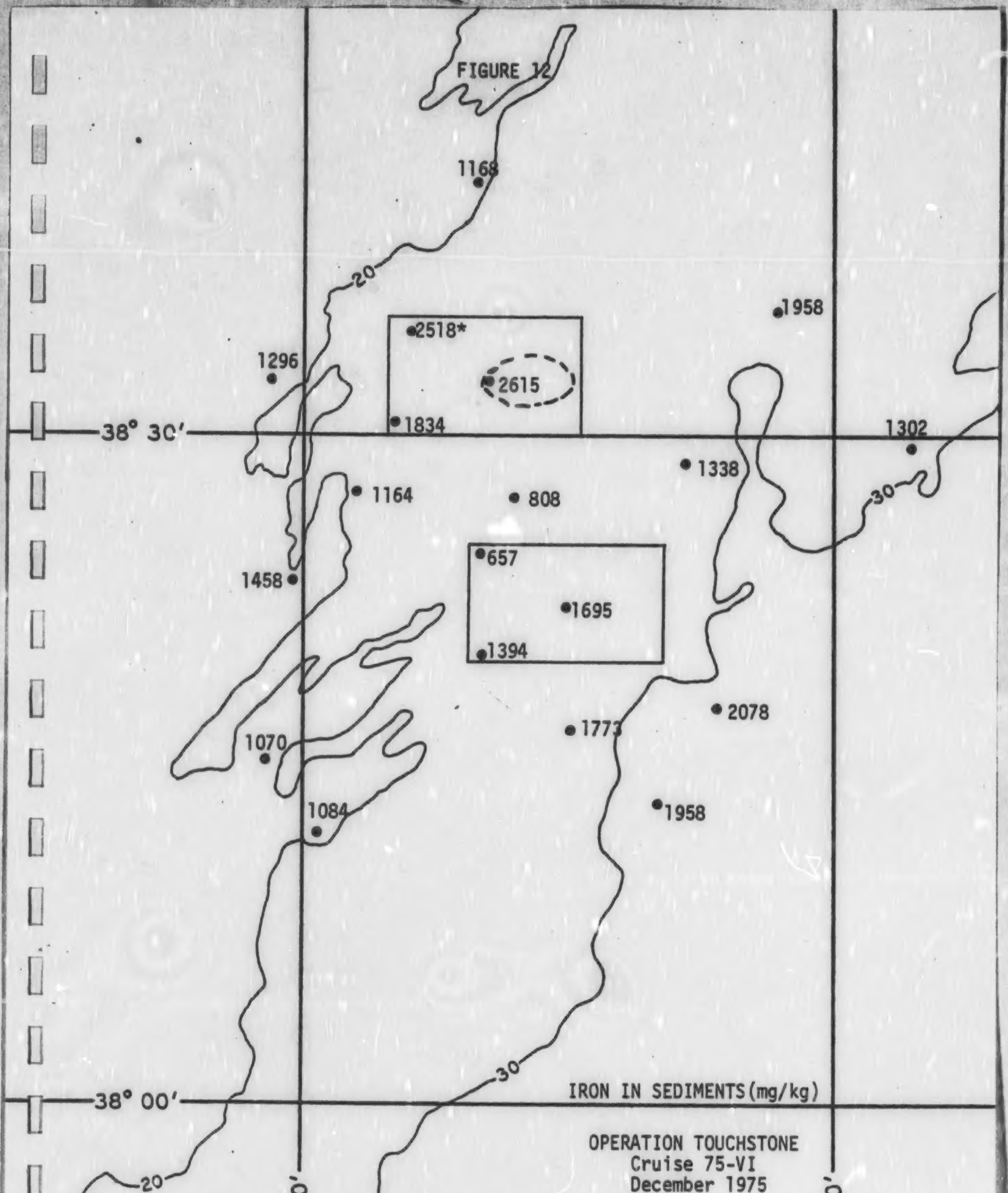

633
20
1340
690*
2357
500
417
38° 30′
993
682
447
443
30
773
450
915
663
1280
902
935
1190
693
30
38° 00′
20
74° 30′
74° 00′

TOTAL ORGANIC CARBON IN SEDIMENTS (mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

FIGURE 12

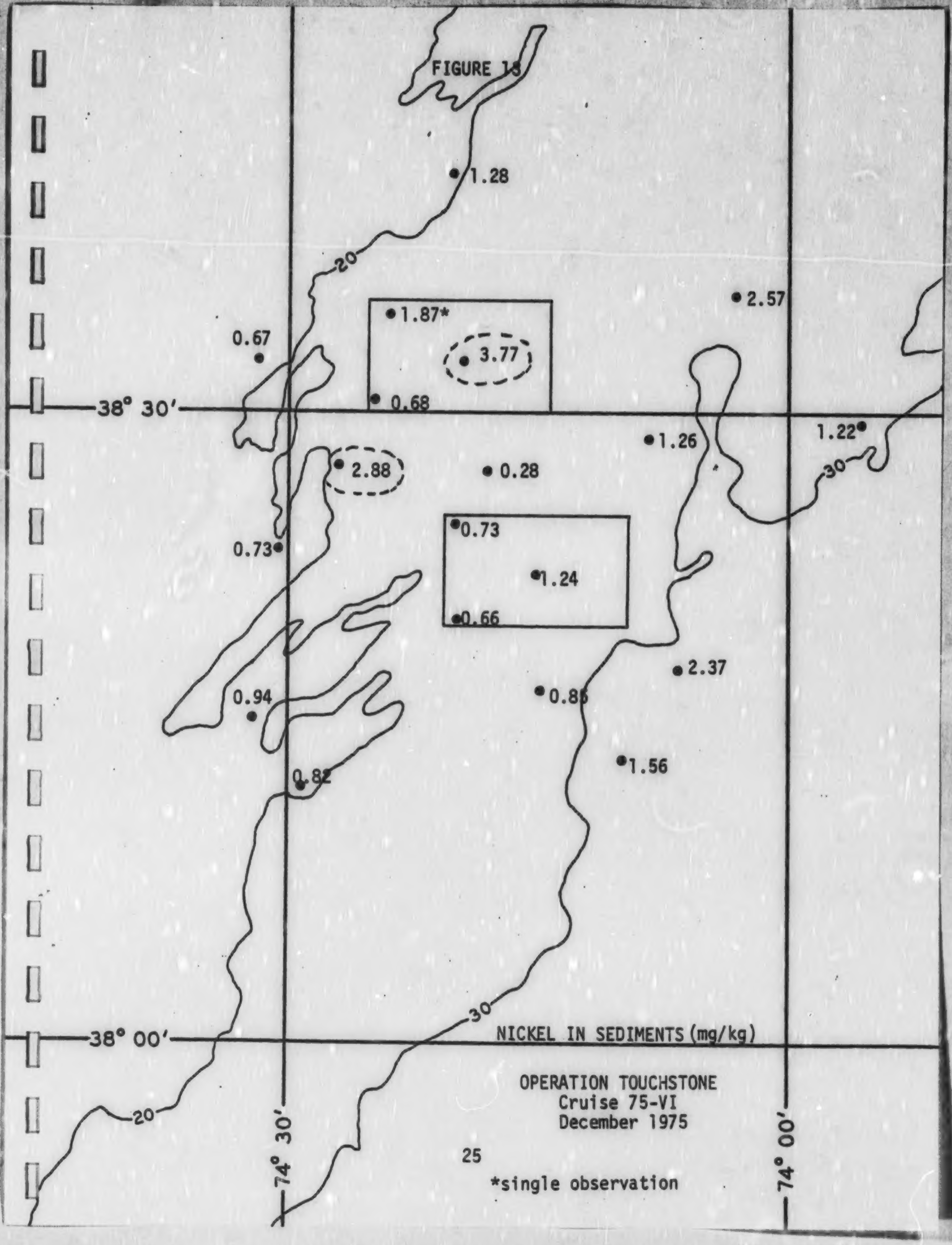

1168
20
2518*
2615
1834
1296
1958
1302
38° 30′
1338
30
1164
808
657
1458
1695
1394
2078
1773
1070
1084
1958
30
38° 00′
20
74° 30′
74° 00′

IRON IN SEDIMENTS(mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

FIGURE 18

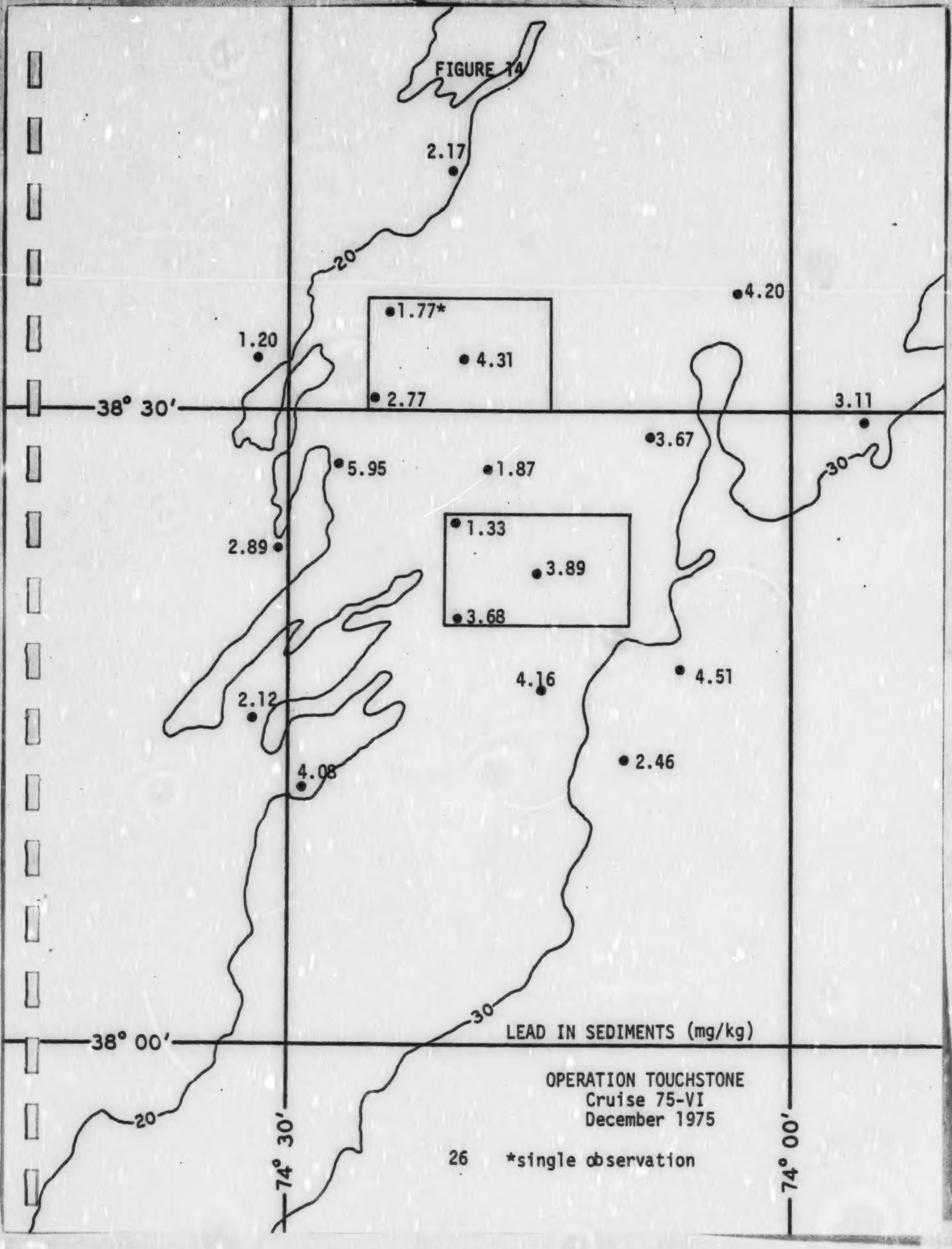

1.28
20
1.87*
3.77
2.57
0.67
0.68
38° 30′
1.26
1.22
2.88
0.28
30
0.73
0.73
1.24
0.66
2.37
0.94
0.85
1.56
0.82
30
38° 00′
20
74° 30′
74° 00′

NICKEL IN SEDIMENTS (mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

FIGURE 14

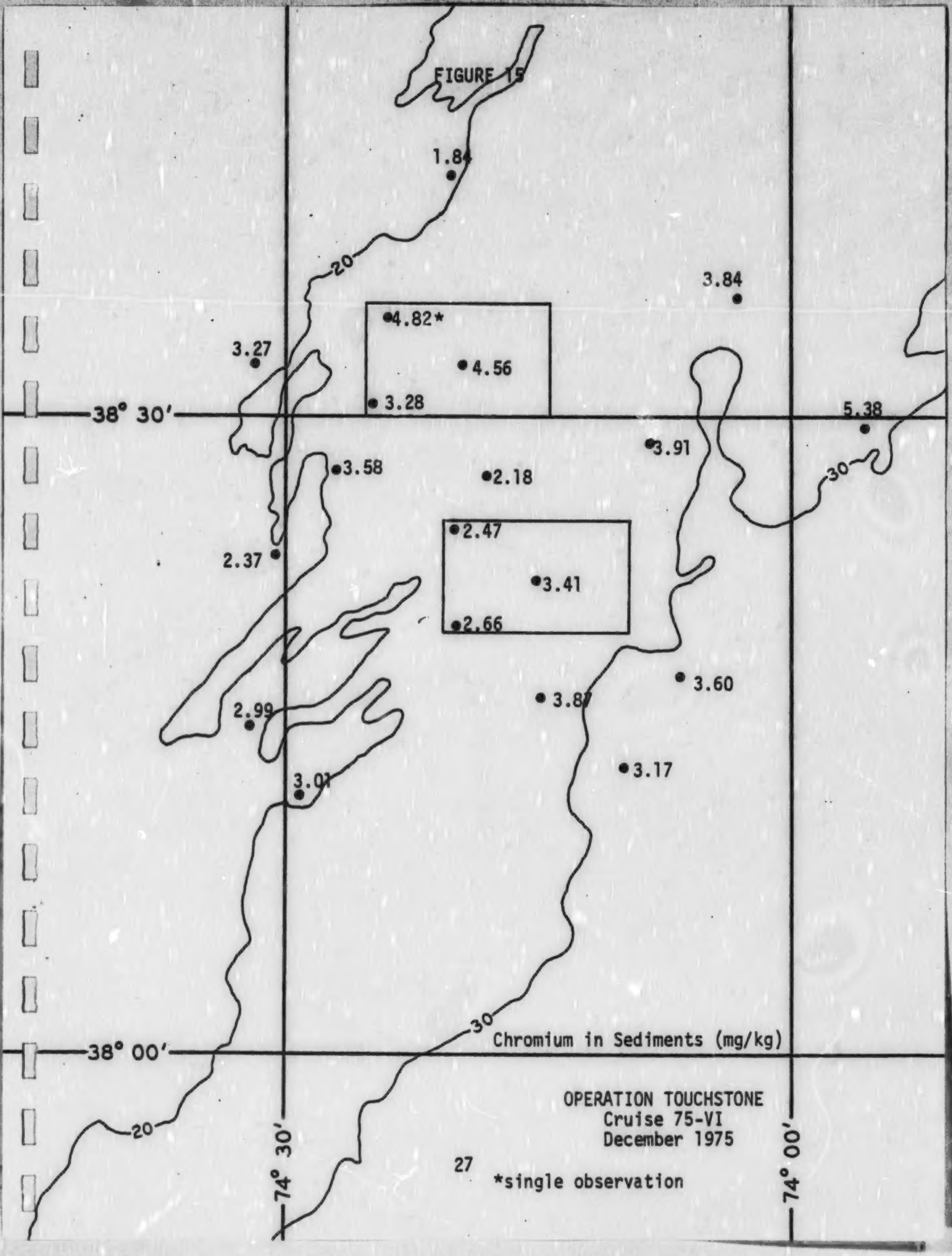

2.17
20
1.77*
4.31
2.77
1.20
4.20
38° 30′
3.11
3.67
5.95
1.87
30
1.33
2.89
3.89
3.68
4.16
4.51
2.12
2.46
4.08
30
38° 00′
20
74° 30′
74° 00′

LEAD IN SEDIMENTS (mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

FIGURE 15

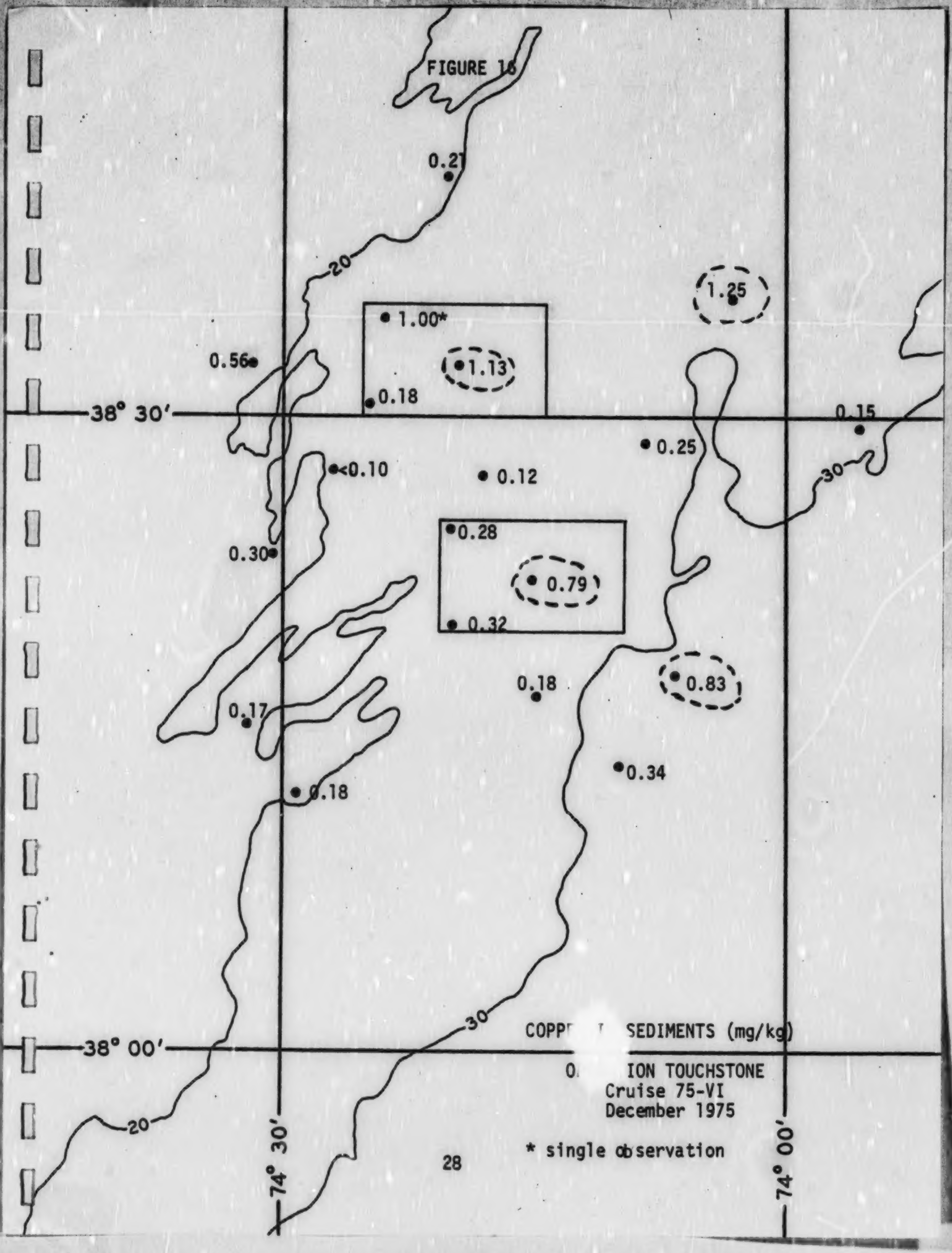

1.84
20
3.84
4.82*
3.27
4.56
3.28
38° 30′
5.38
3.91
3.58
2.18
30
2.47
2.37
3.41
2.66
3.60
3.87
2.99
3.17
3.01
30
38° 00′
20
74° 30′
74° 00′

Chromium in Sediments (mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

FIGURE 16

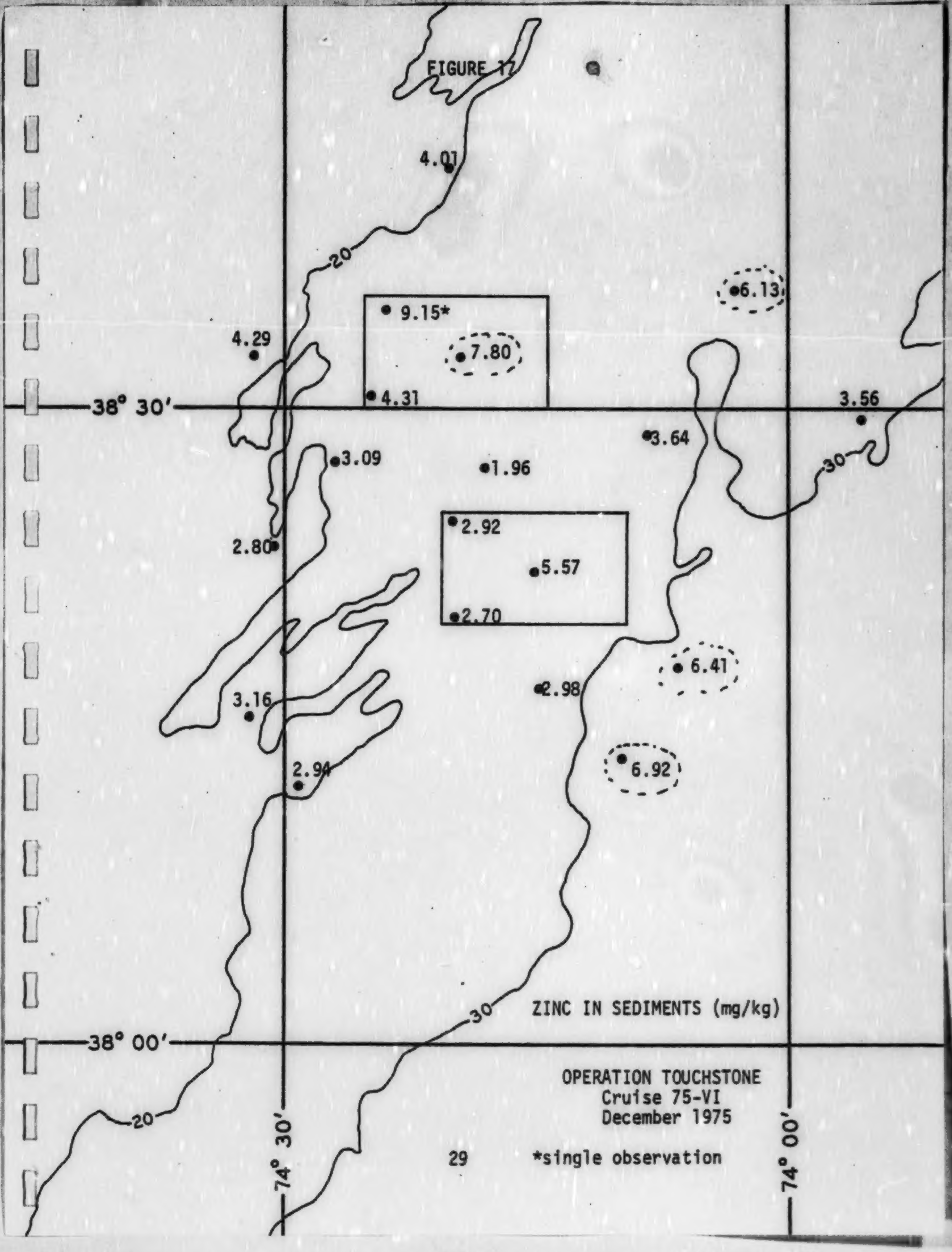

0.27
20
1.25
1.00*
0.56
1.13
0.18
38° 30′
0.15
0.25
<0.10
0.12
30
0.28
0.30
0.79
0.32
0.18
0.83
0.17
0.34
0.18
30
38° 00′
20
74° 30′
74° 00′

COPP[illegible] SEDIMENTS (mg/kg)

O[illegible]ION TOUCHSTONE
Cruise 75-VI
December 1975

* single observation

FIGURE 17


4.01
20
9.15*
7.80
4.29
4.31
6.13
38° 30'
3.56
3.64
3.09
1.96
30
2.92
2.80
5.57
2.70
6.41
2.98
3.16
6.92
2.94
30
38° 00'
20
74° 30'
74° 00'

ZINC IN SEDIMENTS (mg/kg)

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

*single observation

TABLE 4

METALS IN SEDIMENTS (mg/kg)
Operation Hotspot - Cruise 76-II
Duncan's Multiple Range Test
Historical Stations

TOC

Station	Mean
A	253
17	270
E	273
23	333
32	386
14	490
8	525
33	530
24	730
22	746
F	833
G-34	836
B	846
2	935
C	1150
G-19	1426
9	1486
20	1540

ANOVA

	df	sos	ms	F
Between	17	8972064	527768	8.55**
Within	34	2096967	61675	
Total	51	11069031		

Chromium

Station	Mean
17	1.53
2	2.23
D	2.40
A	2.47
32	2.67
24	2.77
8	2.80
14	3.00
G-34	3.00
33	3.30
E	3.30
23	3.33
G-19	3.63
22	3.67
F	3.83
C	3.97
B	4.27
9	4.35
20	6.27

ANOVA

	df	sos	ms	F
Between	18	57.01	3.17	26.56**
Within	37	4.41	0.12	
Total	55	61.42		

TABLE 5

METALS IN SEDIMENTS (mg/kg)
Operation Hotspot - Cruise 76-II
Duncan's Multiple Range Test
Historical Stations

Nickel

Station	Mean
2	0.13
A	0.30
B	0.33
22	0.37
33	0.37
24	0.43
14	0.43
G-34	0.80
C	0.80
F	0.90
9	0.97
G-19	1.30
20	1.63

ANOVA

	df	sos	ms	F
Between	11	6.80	0.62	36.00
Within	26	0.45	0.02	-
Total	37	7.25	-	-

Lead

Station	Mean
F	0.50
2	0.50
22	0.57
B	0.70
9	0.97
14	1.05
E	1.27
G-34	1.47
24	1.60
8	1.60
G-19	1.77
23	1.77
20	2.20

ANOVA

	df	sos	ms	F
Between	12	10.75	0.90	1.19
Within	23	17.24	0.85	-
Total	35	28.00	-	-

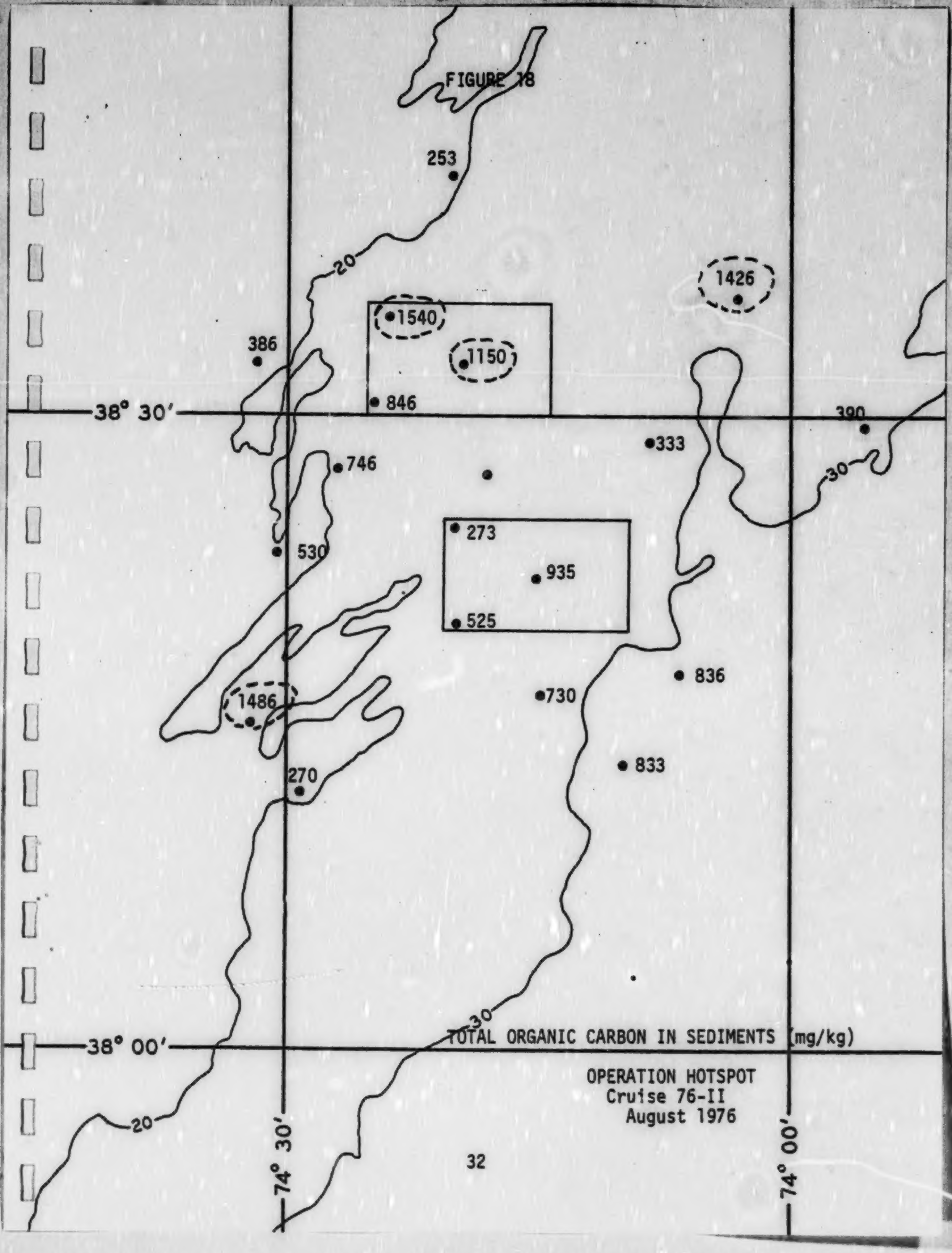
Zinc

Station	Mean
D	1.67
17	2.30
32	2.53
23	2.83
14	3.00
8	3.13
A	3.20
E	3.80
2	4.20
22	4.20
33	4.73
24	5.03
B	5.43
9	5.50
G-34	5.70
F	6.16
C	7.07
G-19	7.57
20	11.63

ANOVA

	df	sos	ms	F
Between	17	279.60	16.45	16.03
Within	39	40.01	1.02	-
Total	56	319.61	-	-

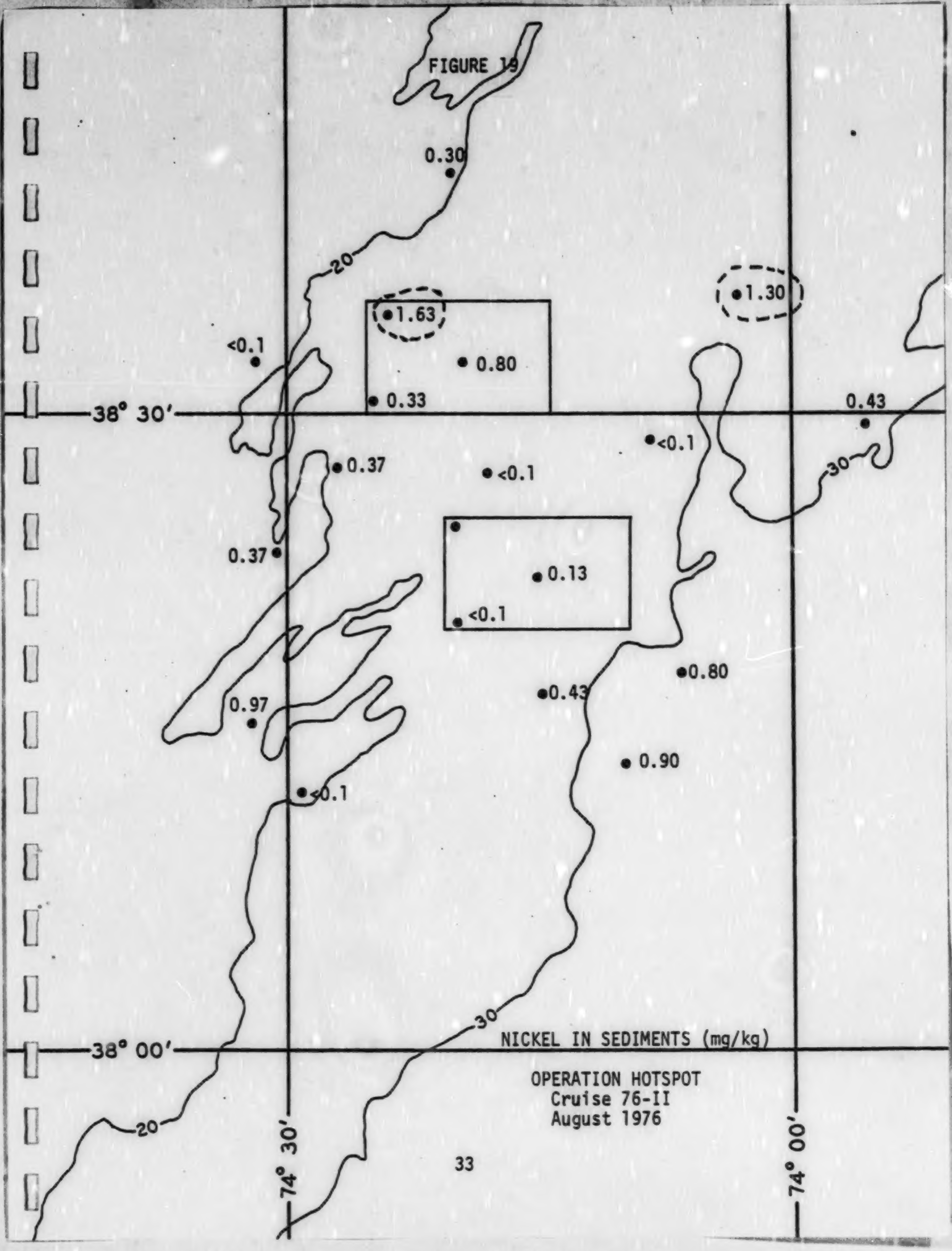
FIGURE 18


253
20
1540
1150
846
386
38° 30′
1426
390
333
30
746
273
935
525
530
836
730
1486
833
270
30
38° 00′
20
74° 30′
74° 00′

TOTAL ORGANIC CARBON IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

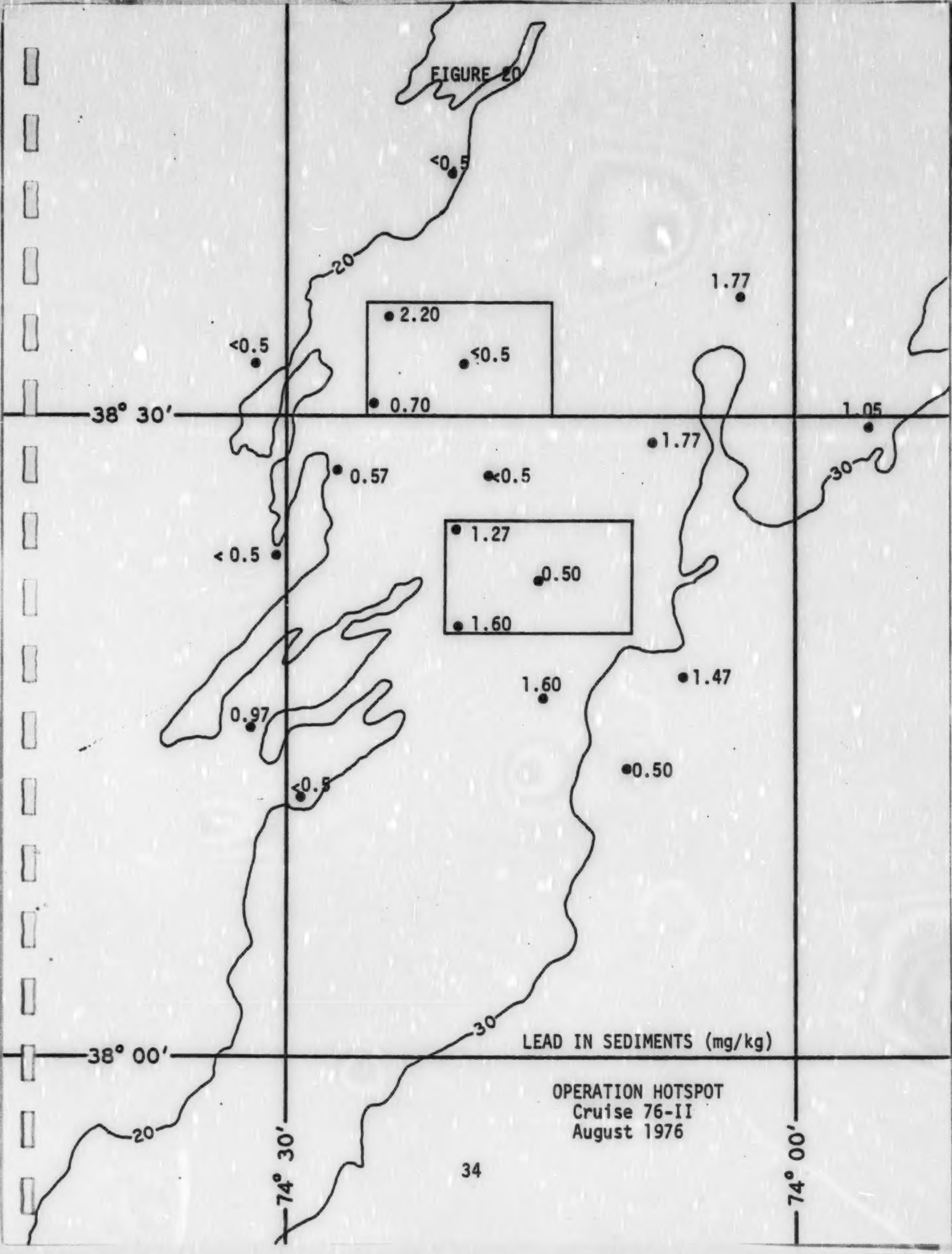
FIGURE 19


0.30
20
<0.1
1.63
0.80
0.33
1.30
0.43
38° 30′
<0.1
0.37
<0.1
30
0.37
0.13
<0.1
0.80
0.43
0.97
0.90
<0.1
30
38° 00′
20
74° 30′
74° 00′

NICKEL IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

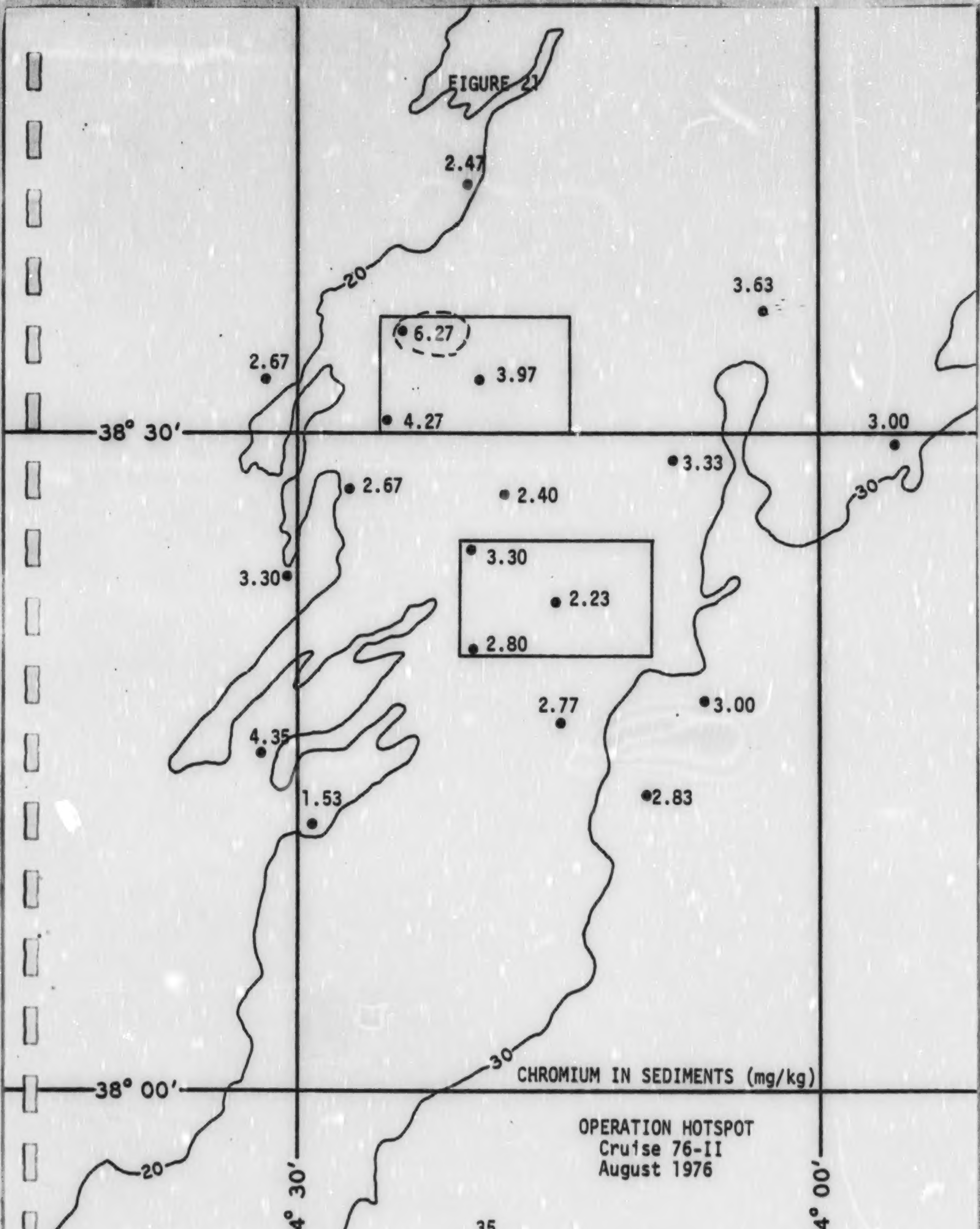
FIGURE 20


20
20
30
30
38° 30′
38° 00′
74° 30′
74° 00′
<0.5
1.77
2.20
<0.5
<0.5
0.70
1.05
1.77
0.57
<0.5
1.27
< 0.5
0.50
1.60
1.47
1.60
0.97
0.50
<0.5

LEAD IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

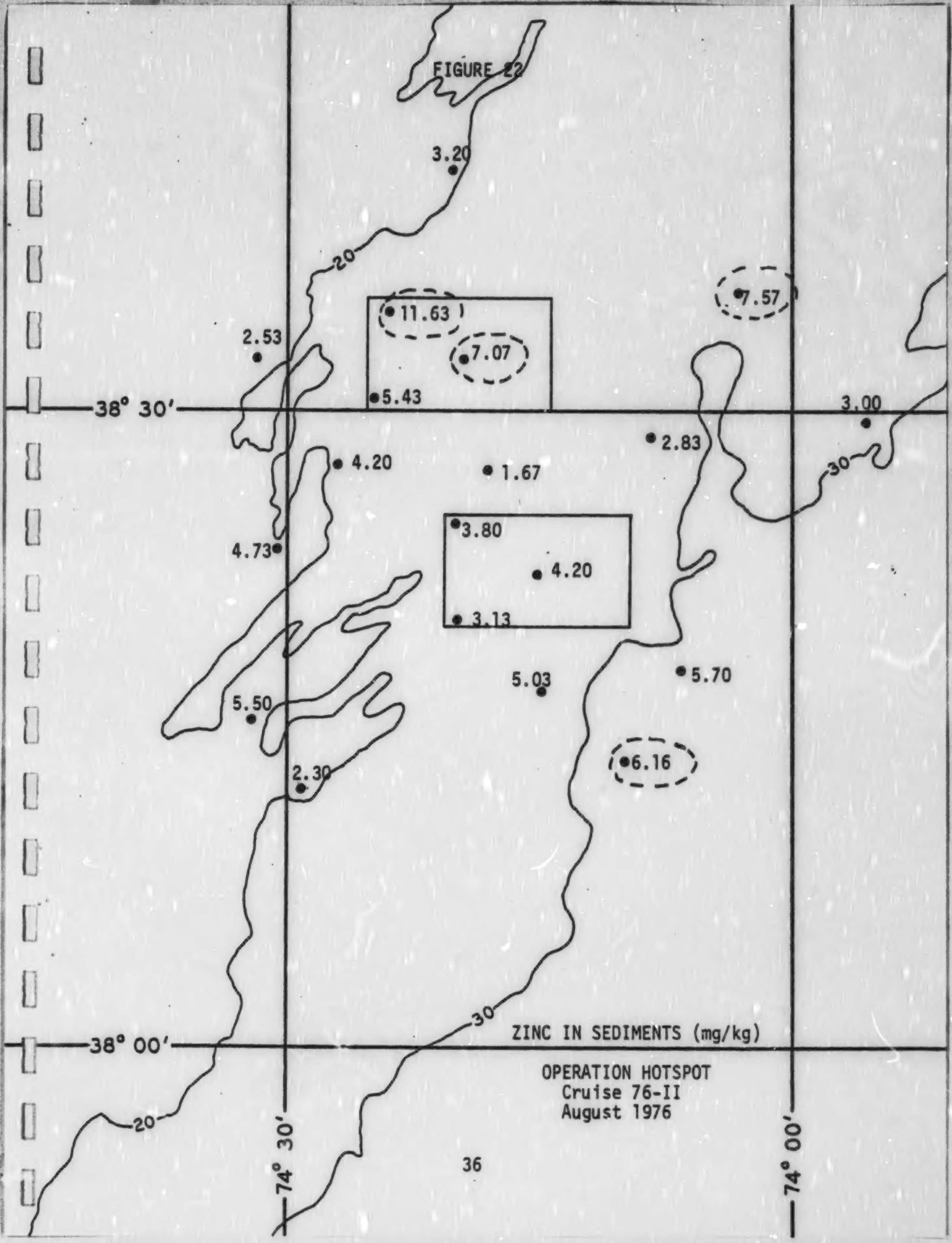
FIGURE 21


2.47
20
3.63
6.27
3.97
2.67
4.27
38° 30′
3.00
3.33
2.67
2.40
30
3.30
3.30
2.23
2.80
2.77
3.00
4.35
2.83
1.53
30
38° 00′
20
74° 30′
74° 00′

CHROMIUM IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

FIGURE 22


3.20
20
2.53
11.63
7.07
5.43
7.57
38° 30′
3.00
2.83
4.20
1.67
30
3.80
4.73
4.20
3.13
5.70
5.03
5.50
6.16
2.30
30
38° 00′
20
74° 30′
74° 00′

ZINC IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

TABLE 6

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
Historical Stations

TOC		Chromium		Nickel	
Station	Mean	Station	Mean	Station	Mean
G-34	77	E	1.77	E	0.70
D	156	17	1.77	23	0.80
33	176	2	2.03	2	0.83
9	250	8	2.13	8	0.83
A	290	D	2.17	B	0.90
2	386	A	2.23	D	0.97
23	386	24	2.37	33	0.97
17	393	G-34	2.40	17	1.00
32	413	23	2.50	32	1.20
E	453	G-19	2.63	A	1.20
B	486	14	2.73	24	1.23
8	493	33	2.73	14	1.40
14	593	F	2.97	C	1.73
C	713	32	3.37	G-34	1.73
F	820	C	3.47	F	1.77
24	850	9	3.73	22	1.83
22	1036	B	3.80	9	2.53
G-19	1176	22	4.37	G-19	2.63
20	1680	20	6.17	20	3.60

ANOVA

	df	sos	ms	F
Between	18	6827815	379323	4.8**
Within	38	2996264	78717	
Total	56	9819079		

ANOVA

	df	sos	ms	F
Between	17	44.45	2.61	3.94**
Within	39	25.89	0.66	
Total	56	70.34		

ANOVA

	df	sos	ms	F
Between	17	31.23	1.84	14.18**
Within	39	5.05	0.13	
Total	56	36.29		

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
Historical Stations

Copper, mg/kg

Station	Mean
D	0.27
33	0.27
23	0.37
B	0.40
17	0.40
A	0.50
14	0.50
C	0.56
Z	0.57
24	0.57
F	0.63
8	0.70
32	0.70
G-34	0.70
E	0.73
9	0.97
G-19	0.97
22	1.13
20	1.97

ANOVA

	df	sos	ms	F
Between	18	8.19	0.455	10.55**
Within	38	1.64	0.04	
Total	56	9.83		

Lead, mg/kg

Station	Mean
23	0.85
D	1.05
14	1.33
32	1.60
33	1.77
A	1.90
24	2.03
8	2.35
2	2.40
G-34	2.40
B	2.50
22	2.60
9	2.67
F	2.80
E	2.83
C	3.27
20	3.30
G-19	4.07

ANOVA

	df	sos	ms	F
Between	18	53.15	2.95	2.58**
Within	38	43.50	1.14	
Total	56	96.65		

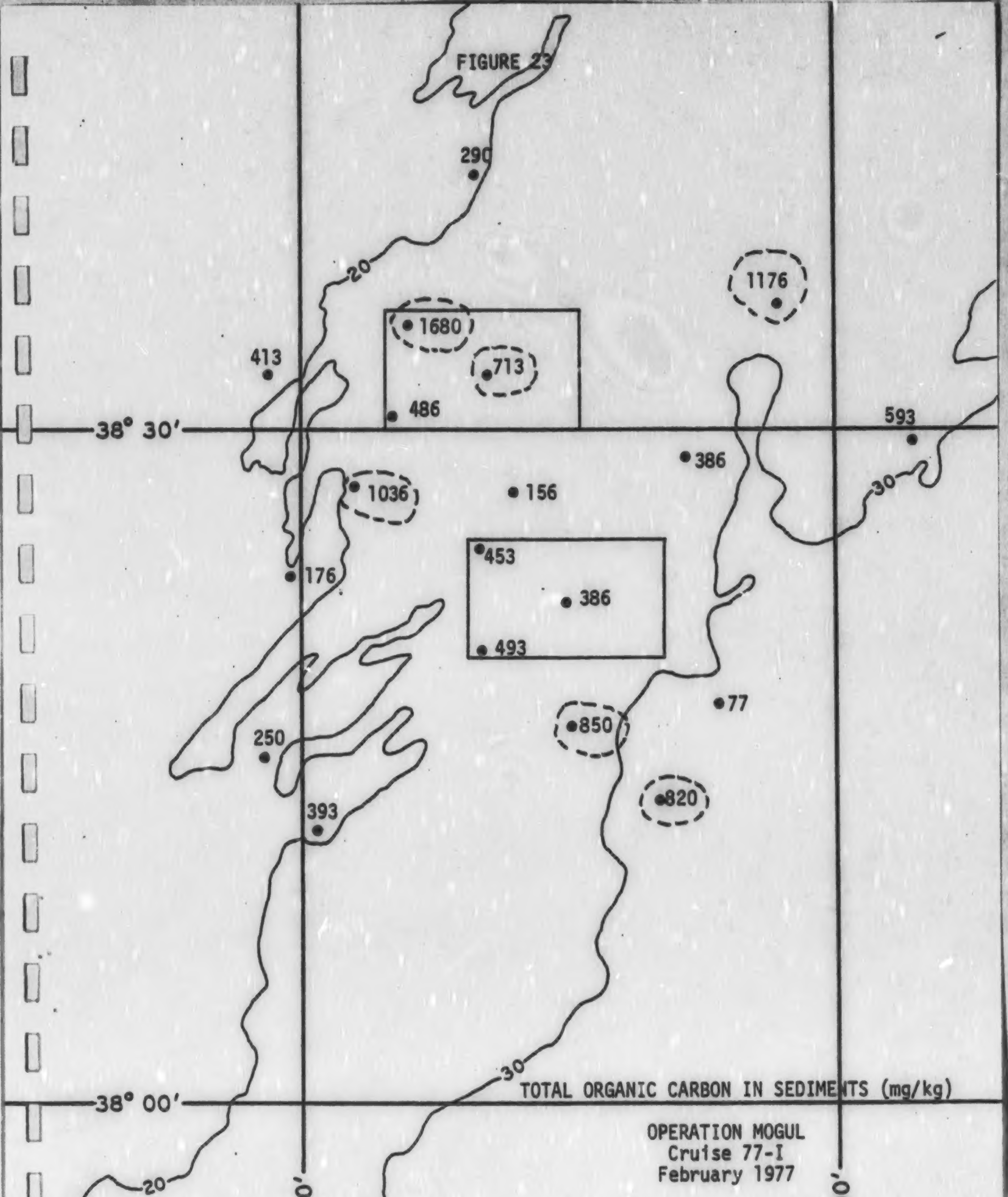
Zinc, mg/kg

Station	Mean
D	3.43
8	3.77
23	4.23
33	4.23
2	4.70
A	4.73
24	4.97
17	4.97
14	5.07
E	5.27
B	6.30
F	6.67
32	7.10
G-34	7.23
C	7.83
G-19	8.70
22	8.80
9	9.13
20	13.77

ANOVA

	df	sos	ms	F
Between	17	338.61	19.92	13.51**
Within	39	57.48	1.47	
Total	56	396.09		

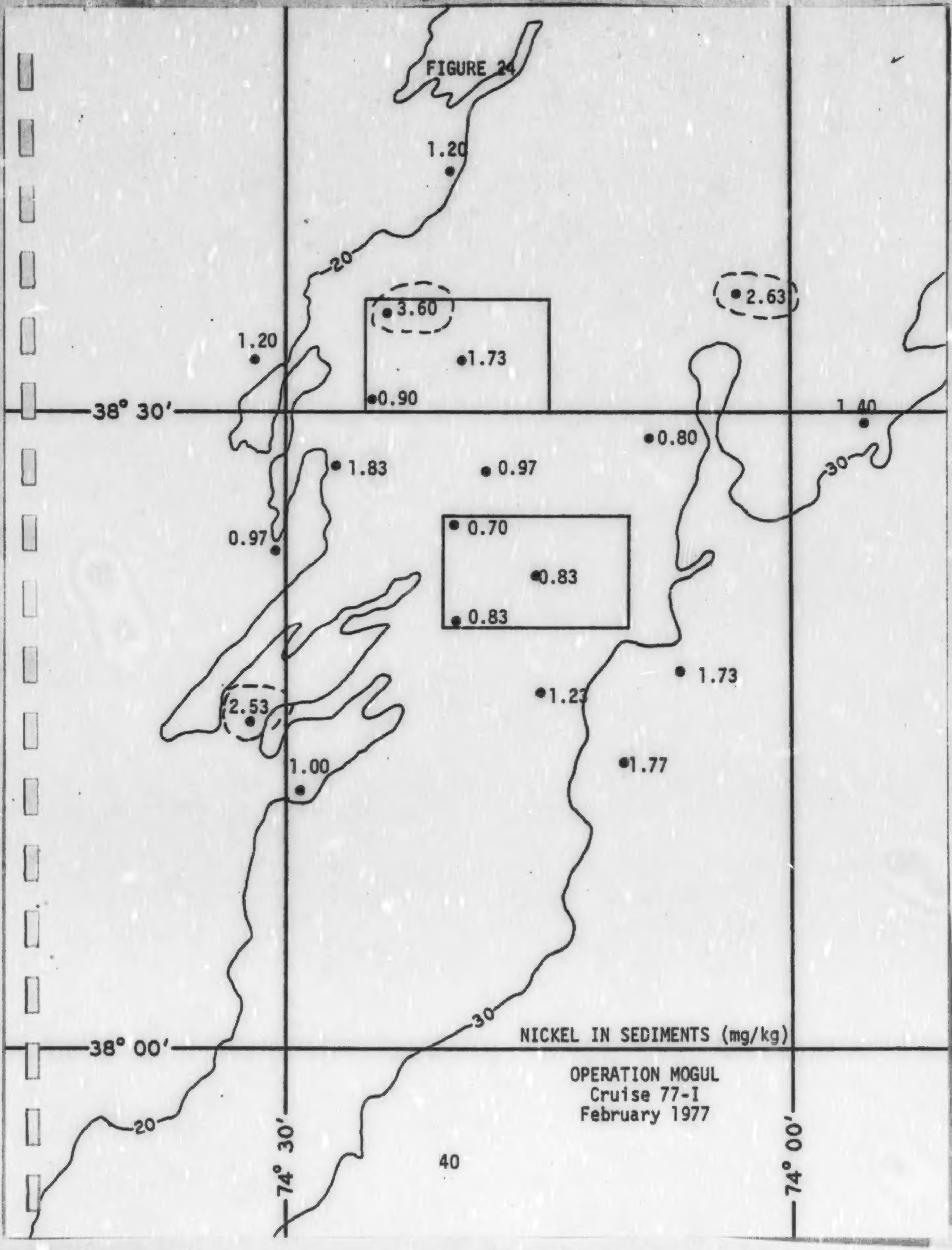
FIGURE 23


290
20
1176
1680
413
713
486
38° 30′
593
386
30
1036
156
453
176
386
493
77
850
250
820
393
30
38° 00′
20
74° 30′
74° 00′

TOTAL ORGANIC CARBON IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

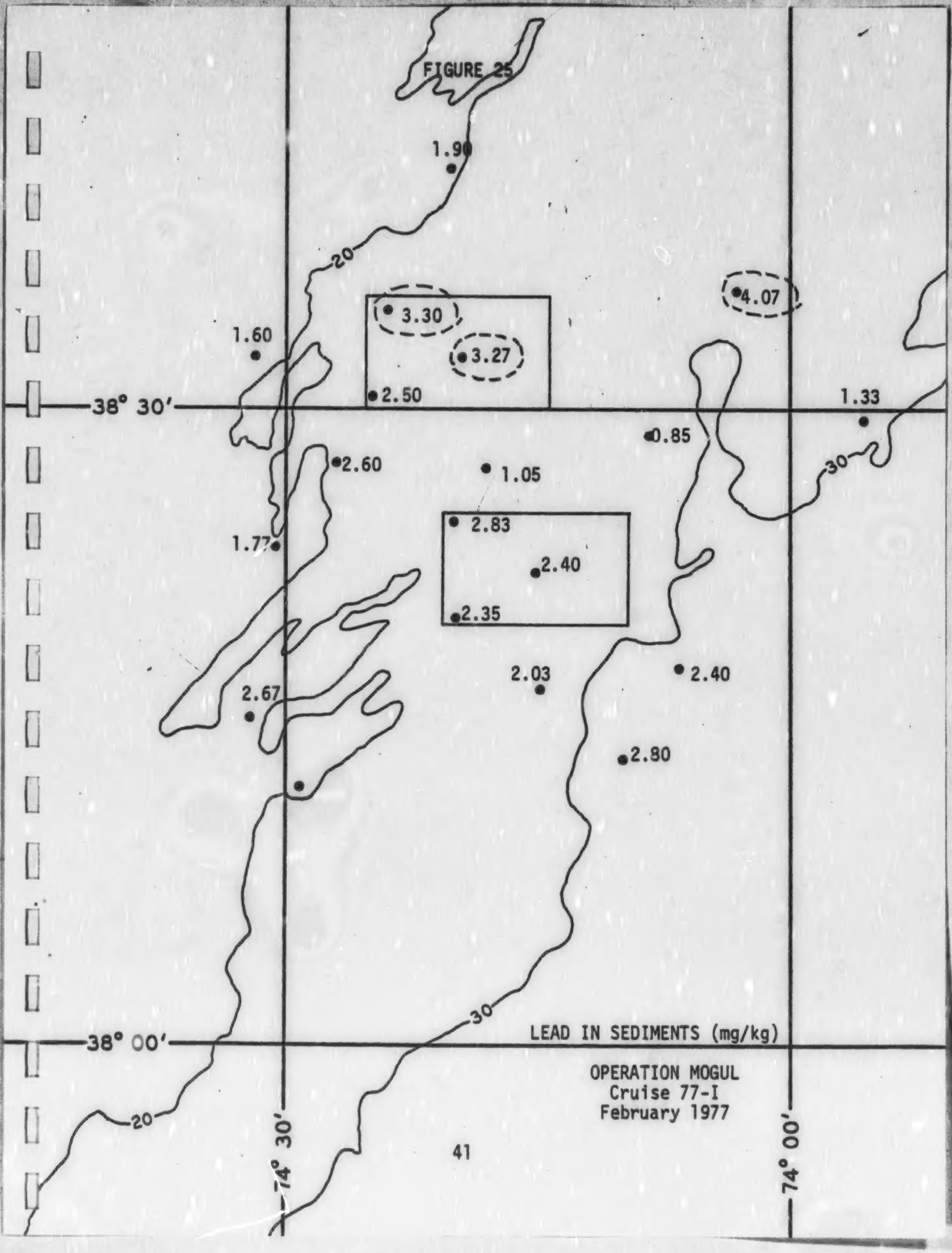
FIGURE 24


1.20
20
3.60
2.63
1.20
1.73
0.90
38° 30′
1.40
0.80
1.83
0.97
30
0.97
0.70
0.83
0.83
1.73
1.23
2.53
1.77
1.00
30
38° 00′
20
74° 30′
74° 00′

NICKEL IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

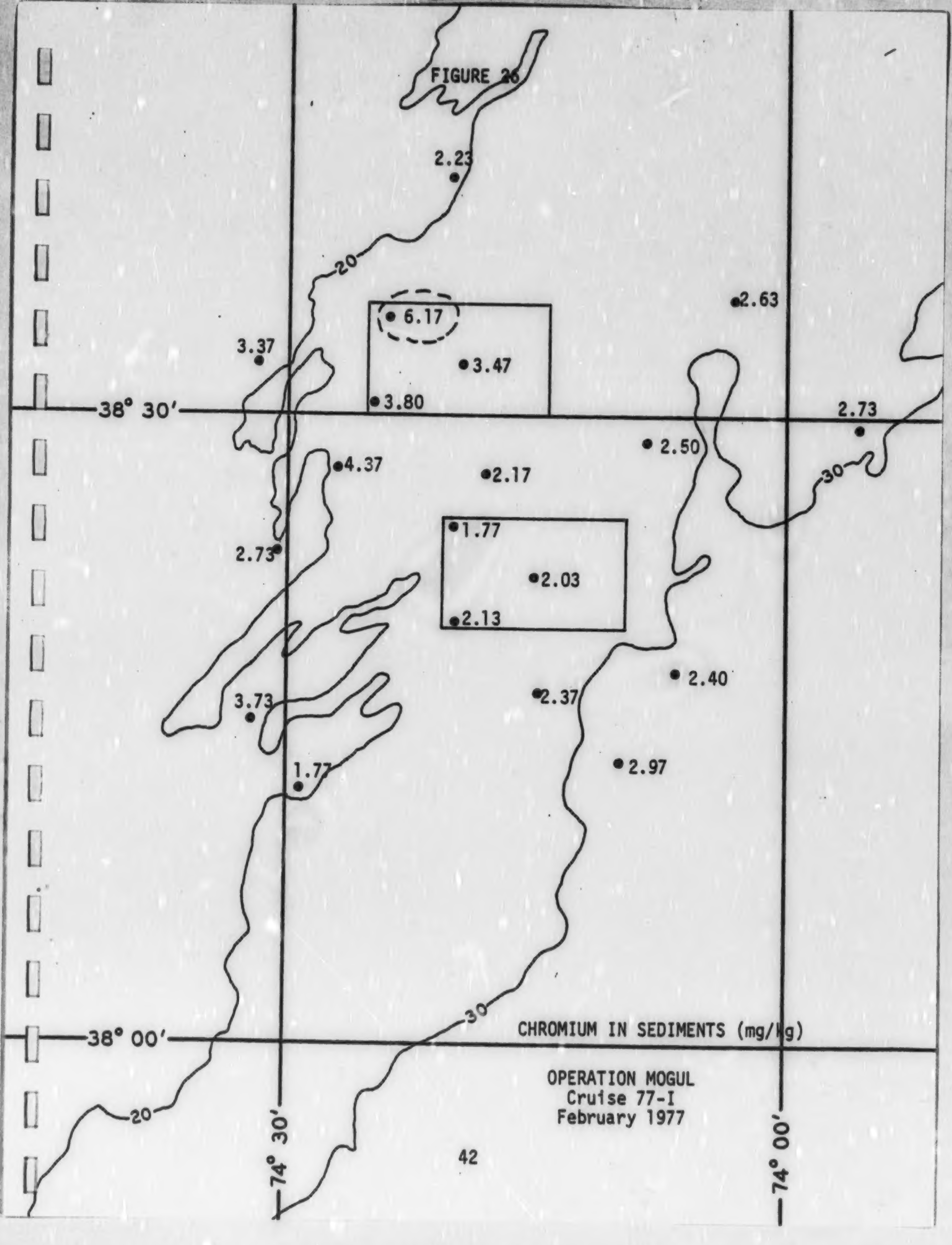
FIGURE 25


1.90
20
1.60
3.30
3.27
2.50
4.07
1.33
38° 30′
0.85
2.60
1.05
30
2.83
1.77
2.40
2.35
2.03
2.40
2.67
2.80
30
38° 00′
20
74° 30′
74° 00′

LEAD IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

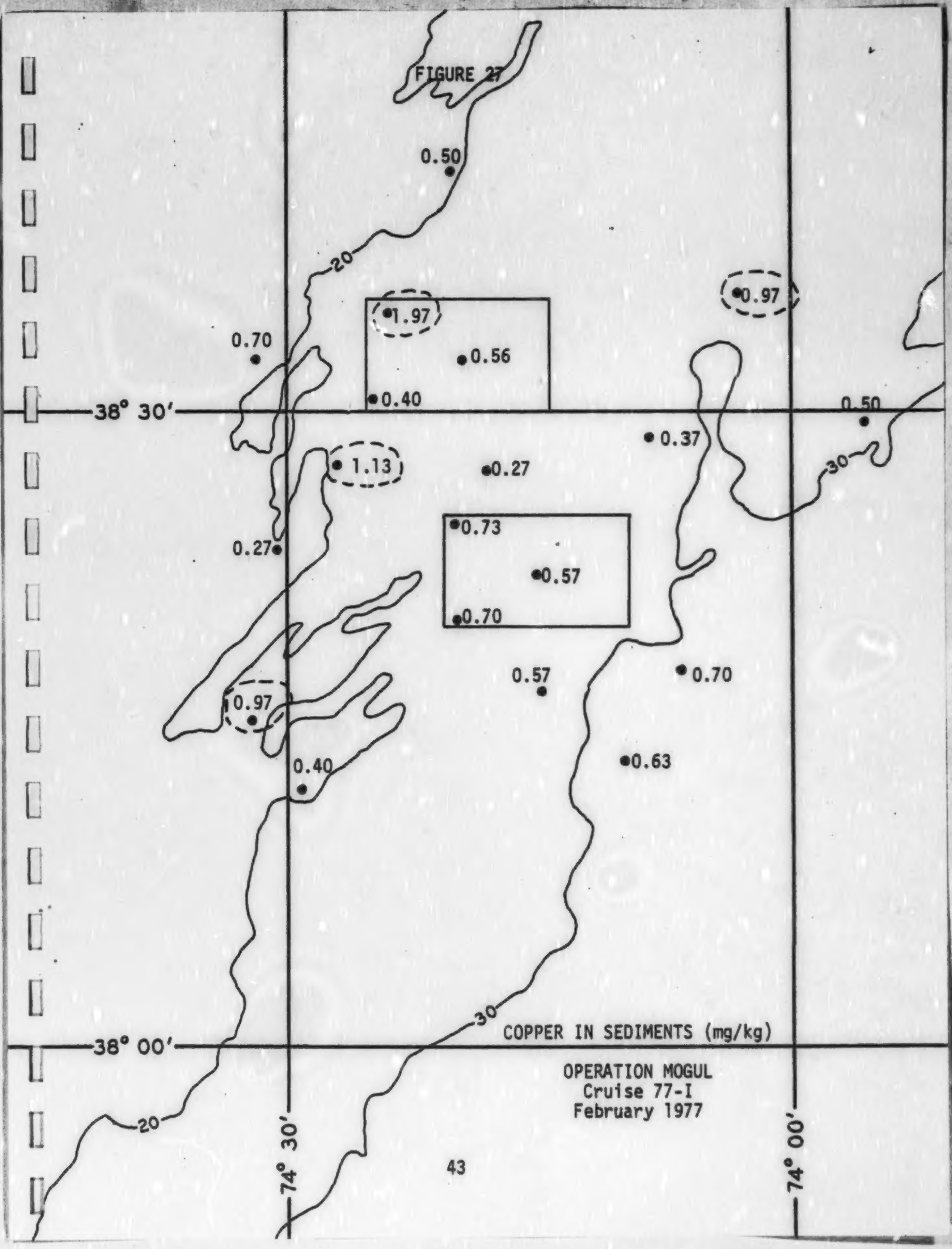
FIGURE 26


2.23
20
6.17
3.47
3.80
3.37
2.63
2.73
38° 30'
2.50
4.37
2.17
30
1.77
2.73
2.03
2.13
2.40
3.73
2.37
2.97
1.77
30
38° 00'
20
74° 30'
74° 00'

CHROMIUM IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

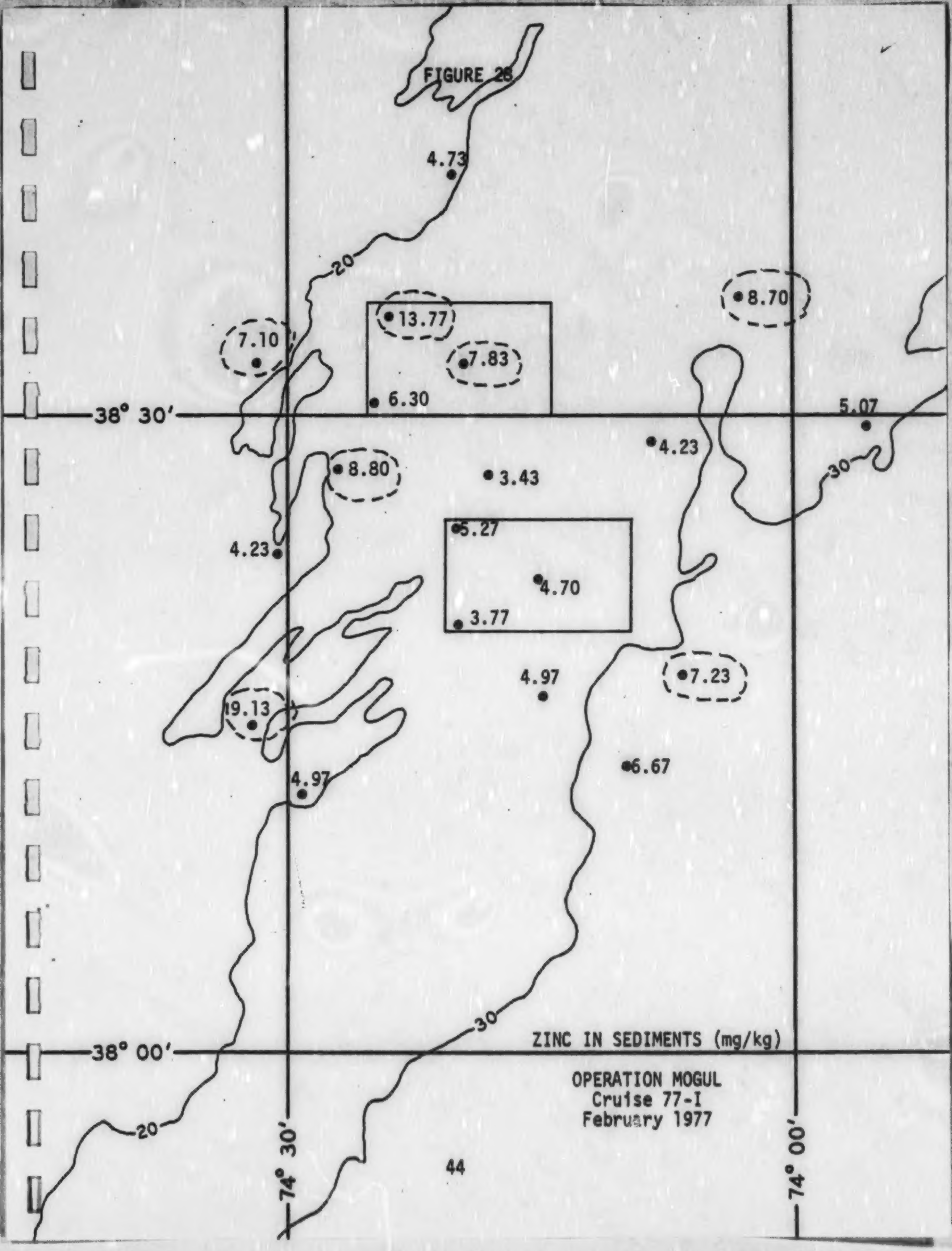
FIGURE 27


0.50
20
0.97
1.97
0.70
0.56
0.40
38° 30′
0.50
0.37
1.13
0.27
30
0.73
0.27
0.57
0.70
0.57
0.70
0.97
0.63
0.40
30
38° 00′
20
74° 30′
74° 00′

COPPER IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

FIGURE 28


4.73
20
13.77
7.83
7.10
6.30
8.70
38° 30′
5.07
4.23
8.80
3.43
30
5.27
4.23
4.70
3.77
4.97
7.23
19.13
6.67
4.97
30
38° 00′
20
74° 30′
74° 00′

ZINC IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

TEMPORAL TRENDS OF METALS IN SEDIMENTS

Considering temporal trends of metals on the continental shelf, Table 8 shows a summary of mean concentrations of metals at these stations since the inception of the program. Figures 29 , 30, 31, 32, 33 , and 34 show plots of mean, standard deviation and range as a function of time. Cadmium was not graphed because concentrations were generally indeterminate. The means reflect ambient levels of metals in this environment, and show no consistent fluctuations with season or general increases as a function of time. The standard deviations are an index of the normal variation to be expected. The ranges plotted are particularly instructive for discriminating external inputs to the environment, noting the atypical variations are nearly always towards high concentrations. These may affect the means and standard deviations to some extent, but when present such influences can be taken into account.

As has been shown in previous reports (Lear and Pesch, 1975), the metals, with possible exception of lead, show significant linear regressions with iron, which further indicates a relatively stable ambience of these parameters.

The concentrations of iron in sediments, shown in Figure 29, show means of the order of magnitude of 1500-2500 mg/kg dry wt., which probably represents the ambient concentrations. Loadings greater than approximately 3500-4500 mg/kg can be regarded as atypical, and should be further investigated.

Nickel in sediments (Figure 30) shows mean concentrations of the order of magnitude of 1.0-2.0 mg/kg dry wt., and concentrations greater than approximately 2.5 mg/kg should be viewed with suspicion.

The ambient concentrations for chromium in sediments (Figure 31) were indicated to be 2.0-4.0 mg/kg.

Zinc in sediments in this region apparently ranged from 4.0 to 7.0 mg/kg, with aberrant concentrations above levels of approximately 8 mg/kg.

Lead concentrations generally averaged between 2.5 and 3.5 mg/kg, and concentrations greater than 4.5 mg/kg may indicate unusual inputs to this system.

The means of copper concentrations showed more variation than the other metals (Figure 34) but no apparent cyclical or temporal trends were evident. The ambient sediment concentrations would, however, be approximately in the range of 0.5 to 2.0 mg/kg.

Cadmium concentrations, not graphed but shown in Table 8 , were generally found to be less than 1 mg/kg. On the one cruise (Deep Six, August 1974) with actual determinations, the mean at these stations was 0.08 mg/kg dry wt., giving an estimate of ambient levels.

TABLE 8
METALS IN SEDIMENTS
Historical Stations

Station A	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Fetch	<1	2	<1	3034	<1	1	4
Ides	<1	2	<1	1481	1	1	5
Deep Six	0.03	1.24	0.84	1748	0.82	1.21	2.98
Midwatch	<0.06	2.40	0.56	1910	1.25	1.82	4.49
Touchstone	<0.05	1.80	0.22	1168	1.28	2.17	4.01
Hotspot	-	2.47	-	-	0.30	<0.50	3.20
Mogul	-	2.23	0.50	-	1.20	1.90	4.73
Station B							
Fetch	<1	2	<1	3400	1	4	6
Ides	<1	3	<1	2228	1	3	6
Deep Six	0.08	2.83	0.48	3259	1.74	2.96	5.43
Midwatch	<0.06	3.14	0.57	2464	0.86	2.03	5.27
Touchstone	<0.11	3.28	0.19	1835	0.68	2.77	4.31
Hotspot	-	4.27	-	-	0.33	0.70	5.43
Mogul	-	3.80	0.40	-	0.90	2.50	6.30
Station C							
Fetch	<1	5	1	6492	2	7	11
Ides	<1	1	<1	1822	1	2	5
Deep Six	0.07	1.24	3.86	4274	2.68	4.53	10.15
Midwatch	0.06	2.87	0.46	1793	0.86	1.87	3.44
Touchstone	0.05	4.56	1.13	2615	3.77	4.32	7.80
Hotspot	-	3.97	-	-	0.80	<0.50	7.07
Mogul	-	3.47	0.56	-	1.73	3.27	7.83
Station D							
Fetch	-	-	-	-	-	-	-
Ides	<1	2	1	1140	<1	2	3
Deep Six	0.02	1.74	0.36	1505	0.52	1.07	2.09
Midwatch	<0.06	2.21	0.43	1471	0.51	1.52	2.58
Touchstone	<0.05	2.19	<0.13	808	0.28	1.88	1.96
Hotspot	-	2.40	-	-	<0.1	<0.50	1.67
Mogul	-	2.17	0.27	-	0.97	1.05	3.43
Station E							
Fetch	<1	1	<1	1027	<1	<1	3
Ides	<1	1.50	1.50	1395	1	3.50	3.50
Deep Six	0.13	3.38	2.13	2678	1.84	6.83	7.30
Midwatch	<0.06	3.05	2.08	1638	1.08	5.93	7.74
Touchstone	<0.06	2.48	<0.28	657	0.73	1.34	2.92
Hotspot	-	3.30	-	-	<0.1	1.27	3.80
Mogul	-	1.77	0.73	-	0.70	2.83	5.27

TABLE 8 (cont.)

METALS IN SEDIMENTS

Historical Stations

Station F	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Fetch	-	-	-	-	-	-	-
Ides	<1	2.50	2	1957	1.50	6	5.50
Deep Six	0.12	3.90	1.34	4829	2.80	4.80	9.67
Midwatch	<0.06	3.15	0.68	2255	0.90	4.30	5.05
Touchstone	<0.05	3.17	0.35	1958	1.56	2.46	6.04
Hotspot	-	3.83	-	-	0.90	0.50	6.16
Mogul	-	2.97	0.63	-	1.77	2.80	6.67
Station G-19							
Fetch	-	-	-	-	-	-	-
Ides	<1.00	3.00	1.00	2031	1.00	5.00	7.00
Deep Six	0.08	1.41	0.42	2575	1.04	4.31	5.00
Midwatch	-	-	-	-	-	-	-
Touchstone	0.27	2.84	1.25	1958	1.27	4.20	6.13
Hotspot	-	3.63	-	-	1.30	1.77	7.57
Mogul	-	2.63	0.97	-	2.63	4.07	8.70
Station G-34							
Fetch	-	-	-	-	-	-	-
Ides	-	-	-	-	-	-	-
Deep Six	-	-	-	-	-	-	-
Midwatch	-	-	-	-	-	-	-
Touchstone	0.05	3.60	0.83	2078	2.37	4.51	6.41
Hotspot	-	3.00	-	-	0.80	1.47	5.70
Mogul	-	2.40	0.70	-	1.73	9.50	7.23
Station 2							
Fetch	<1.00	3.00	<1.00	2508	1.00	4.50	5.00
Ides	<1.00	2.60	1.00	2401	1.20	8.20	8.60
Deep Six	0.12	2.07	0.30	2481	0.83	2.91	4.45
Midwatch	<0.06	4.33	1.61	3323	2.11	6.11	10.02
Touchstone	0.05	3.41	0.79	1695	1.24	3.89	5.57
Hotspot	-	2.23	-	-	0.13	0.50	4.20
Mogul	-	2.03	0.57	-	0.83	2.40	4.70
Station 8							
Fetch	<1.00	2.00	<1.00	1548	<1.00	2.00	2.00
Ides	<1.00	2.20	1.40	2179	1.60	8.40	6.80
Deep Six	0.12	0.71	0.26	1993	0.31	2.53	2.45
Midwatch	<0.06	1.55	0.53	1459	0.43	1.75	2.62
Touchstone	0.07	2.66	0.32	1094	0.66	3.68	2.10
Hotspot	-	2.80	-	-	<0.1	1.60	3.13
Mogul	-	2.13	0.70	-	0.83	2.35	3.77

TABLE 8 (cont.)
METALS IN SEDIMENTS

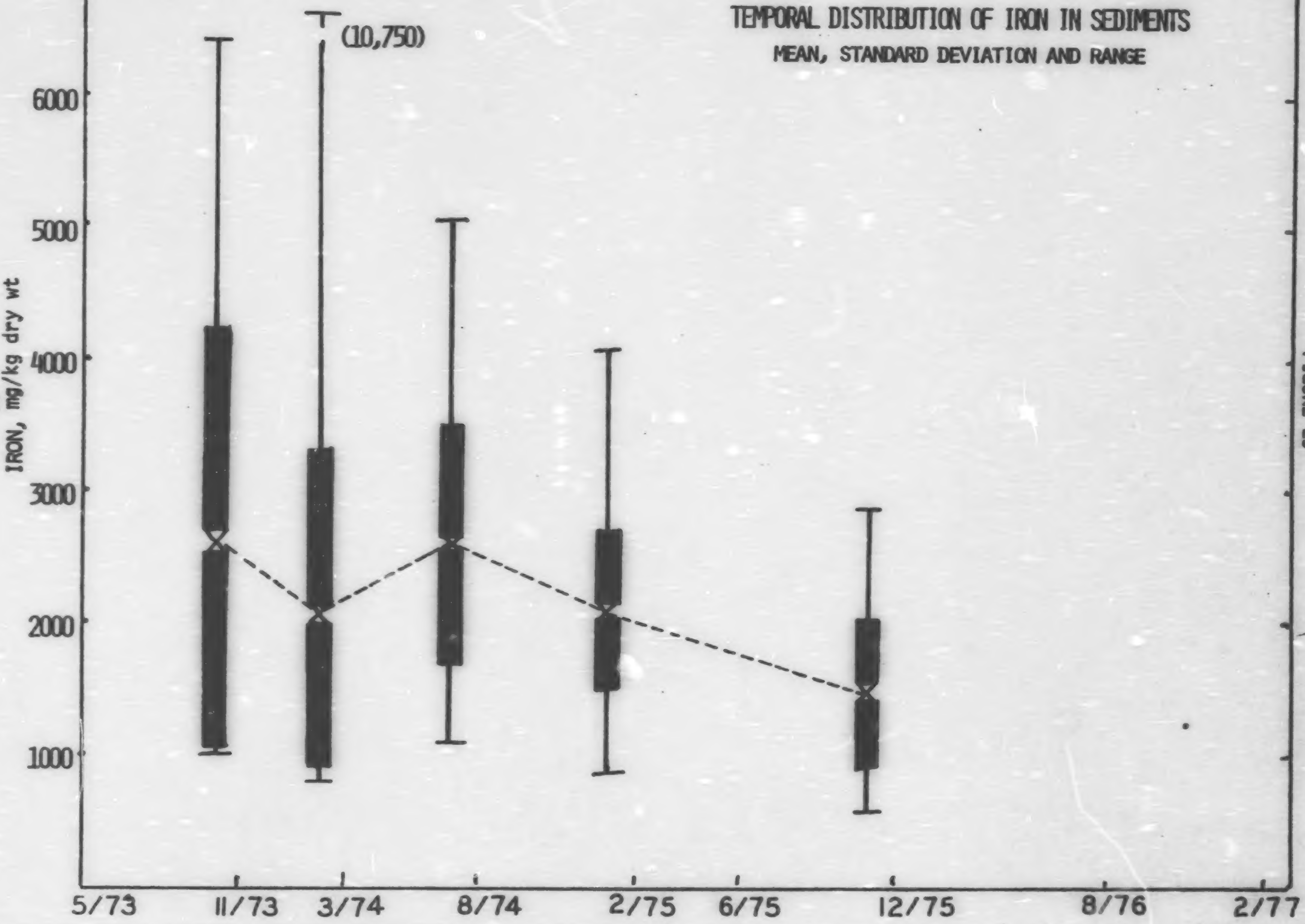
Historical Stations

Station 9	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Fetch	<1.00	1.00	<1.00	2103	<1.00	3.00	4.00
Ides	<1.00	1.20	<1.00	1162	2.20	3.60	3.20
Deep Six	0.06	1.52	0.12	1678	0.78	1.61	3.52
Midwatch	<0.06	2.17	0.65	1644	2.57	2.15	3.39
Touchstone	0.08	2.99	0.17	1070	0.94	2.12	3.16
Hotspot	-	4.35	-	-	0.97	0.97	5.50
Mogul	-	3.73	0.97	-	2.53	2.67	9.13
Station 14							
Fetch	<1.00	3.00	<1.00	2350	1.00	3.00	6.00
Ides	<1.00	3.00	<1.00	1505	<1.00	2.50	4.00
Deep Six	0.10	1.70	0.13	2484	1.02	2.96	4.04
Midwatch	<0.06	2.54	0.53	2185	1.06	2.12	5.14
Touchstone	0.06	5.38	0.15	1302	1.22	3.11	3.56
Hotspot	-	3.00	-	-	0.43	1.05	3.00
Mogul	-	2.73	0.50	-	1.40	<.05	5.07
Station 17							
Fetch	<1.00	2.00	<1.00	1640	1.00	3.00	4.00
Ides	<1.00	3.00	<1.00	1607	2.00	1.00	4.00
Deep Six	0.08	0.76	0.06	2101	0.43	1.88	2.79
Midwatch	<0.06	3.03	6.12	2097	1.78	2.42	4.41
Touchstone	<0.05	3.01	0.18	1084	0.82	4.08	2.94
Hotspot	-	1.53	-	-	<0.1	<0.50	2.30
Mogul	-	1.77	0.40	-	1.00	1.33	4.97
Station 20							
Fetch	-	-	-	-	-	-	-
Ides	<1.00	5.00	1.00	3016	3.00	5.00	11.00
Deep Six	0.08	2.50	0.91	3365	2.44	4.38	8.60
Midwatch	<0.06	4.69	1.49	3792	2.71	4.52	10.25
Touchstone	0.05	4.82	<1.00	2518	1.87	1.77	9.15
Hotspot	-	6.27	-	-	1.63	2.20	11.63
Mogul	-	6.17	1.97	-	3.60	3.30	13.77
Station 22							
Fetch	-	-	-	-	-	-	-
Ides	<1.00	5.00	<1.00	2637	3.00	4.50	8.00
Deep Six	0.06	2.61	0.06	2923	1.22	3.23	4.67
Midwatch	<0.06	3.09	0.89	2643	1.27	2.97	6.23
Touchstone	0.23	3.58	<0.10	1164	2.88	5.95	3.09
Hotspot	-	3.67	-	-	0.37	0.57	4.20
Mogul	-	4.37	1.13	-	1.83	2.60	8.80

TABLE 8 (cont.)
METALS IN SEDIMENTS
Historical Stations

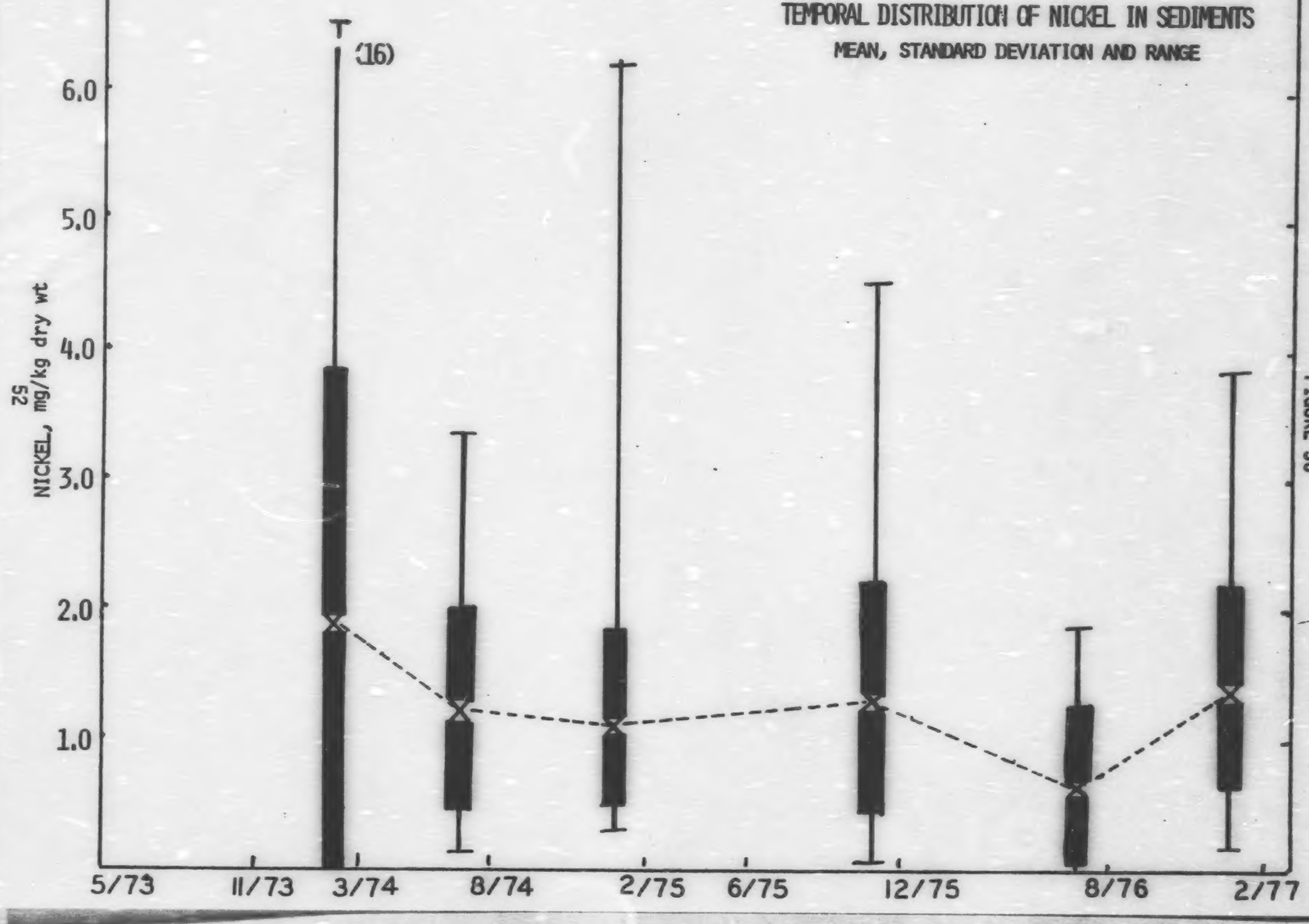
Station 23	Cd	Cr	Cu	Fe	Ni	Pb	Zn
Fetch	-	-	-	-	-	-	-
Ides	<1.00	3.00	<0.10	1992	3.00	4.00	5.00
Deep Six	-	-	-	-	-	-	-
Midwatch	<0.06	2.54	0.43	2004	0.50	2.47	4.16
Touchstone	0.08	3.91	0.22	1338	1.92	3.67	3.45
Hotspot	-	3.33	-	-	<0.1	1.77	2.83
Mogul	-	2.50	0.37	-	0.80	0.85	4.23
Station 24							
Fetch	-	-	-	-	-	-	-
Ides	<1.00	6.50	7.50	6196	8.50	8.50	17.50
Deep Six	0.06	1.30	<0.06	2102	0.78	2.96	2.42
Midwatch	<0.06	2.47	0.51	2038	0.68	4.46	3.81
Touchstone	0.10	3.88	0.26	1887	1.14	4.19	3.80
Hotspot	-	2.77	-	-	0.43	1.60	5.03
Mogul	-	2.37	0.57	-	1.23	2.03	4.97
Station 32							
Fetch	-	-	-	-	-	-	-
Ides	-	-	-	-	-	-	-
Deep Six	0.10	1.30	0.12	2189	0.69	1.21	2.28
Midwatch	<0.06	2.53	0.30	1833	0.79	1.72	3.60
Touchstone	0.11	3.27	0.41	1296	0.67	1.20	4.29
Hotspot	-	2.67	-	-	<0.1	<0.50	2.53
Mogul	-	3.37	0.70	-	1.20	1.60	7.10
Station 33							
Fetch	-	-	-	-	-	-	-
Ides	-	-	-	-	-	-	-
Deep Six	0.06	1.43	0.43	2531	1.16	1.32	3.09
Midwatch	<0.06	2.36	0.59	2195	0.97	2.30	4.49
Touchstone	<0.05	2.37	0.30	1458	0.52	2.89	2.80
Hotspot	-	3.30	-	-	0.37	<0.50	4.73
Mogul	-	2.73	0.27	-	0.97	1.77	4.23
Station							
Fetch							
Ides							
Deep Six							
Midwatch							
Touchstone							
Hotspot							
Mogul							

FIGURE 29



TEMPORAL DISTRIBUTION OF IRON IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

FIGURE 30



TEMPORAL DISTRIBUTION OF NICKEL IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

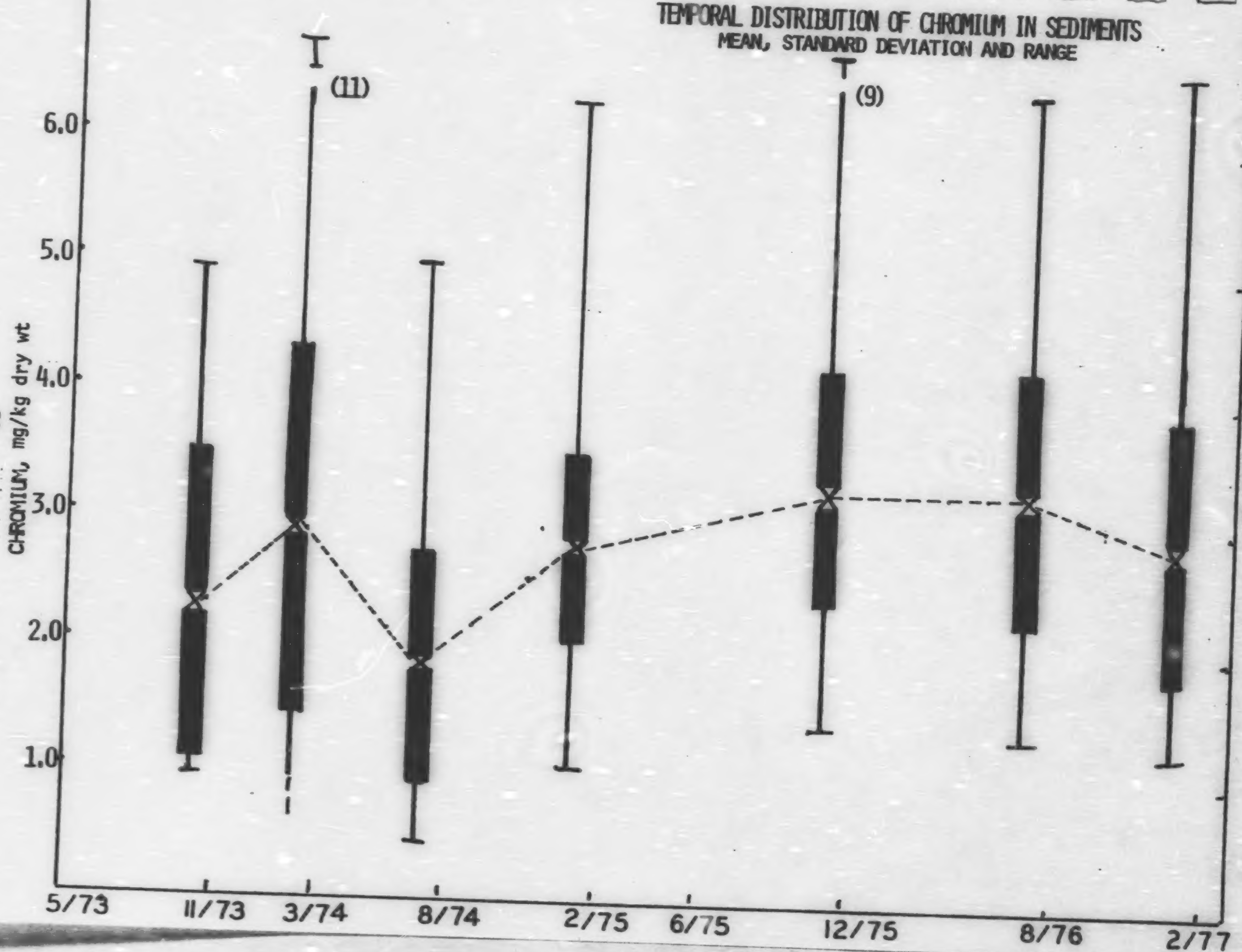
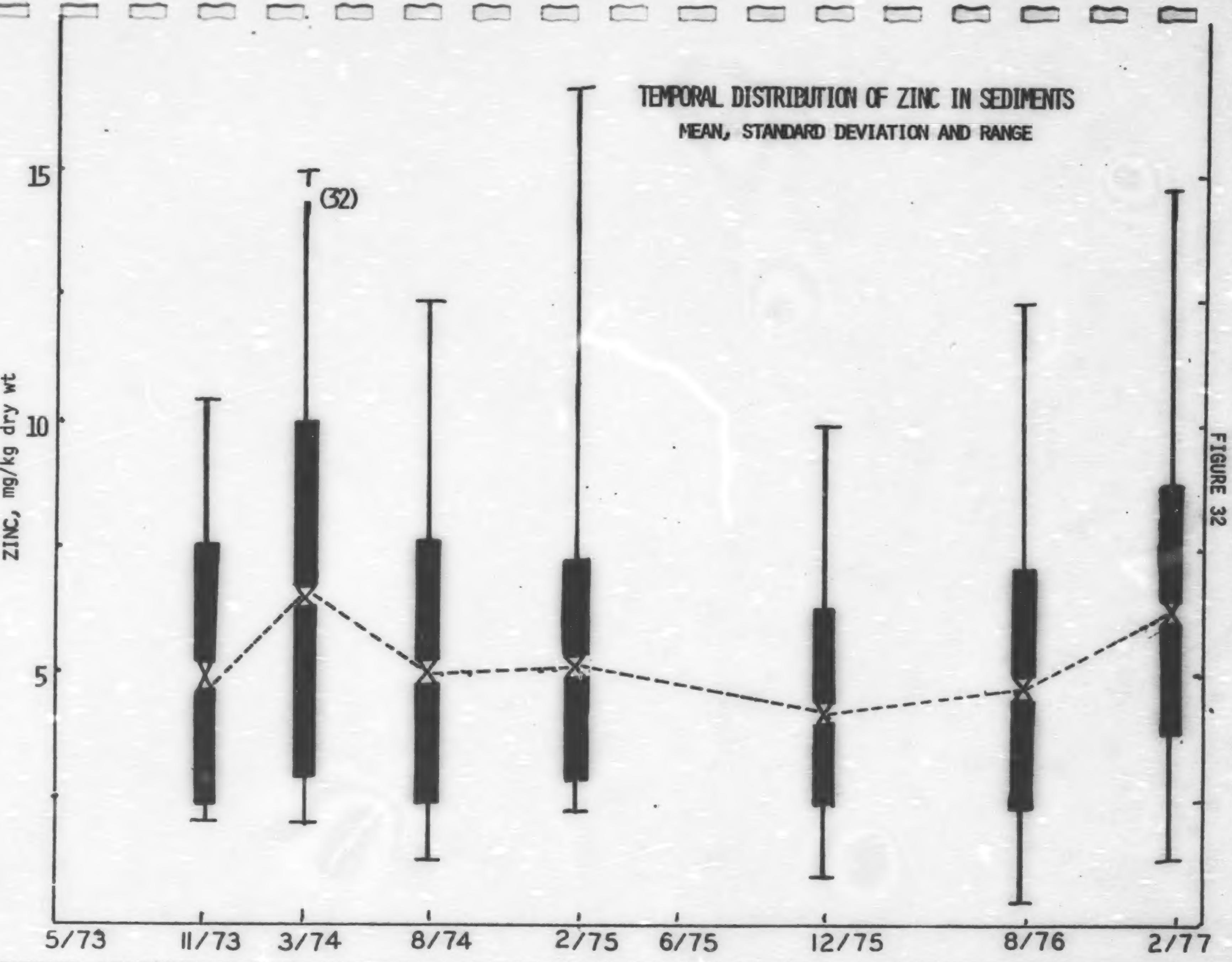


FIGURE 31

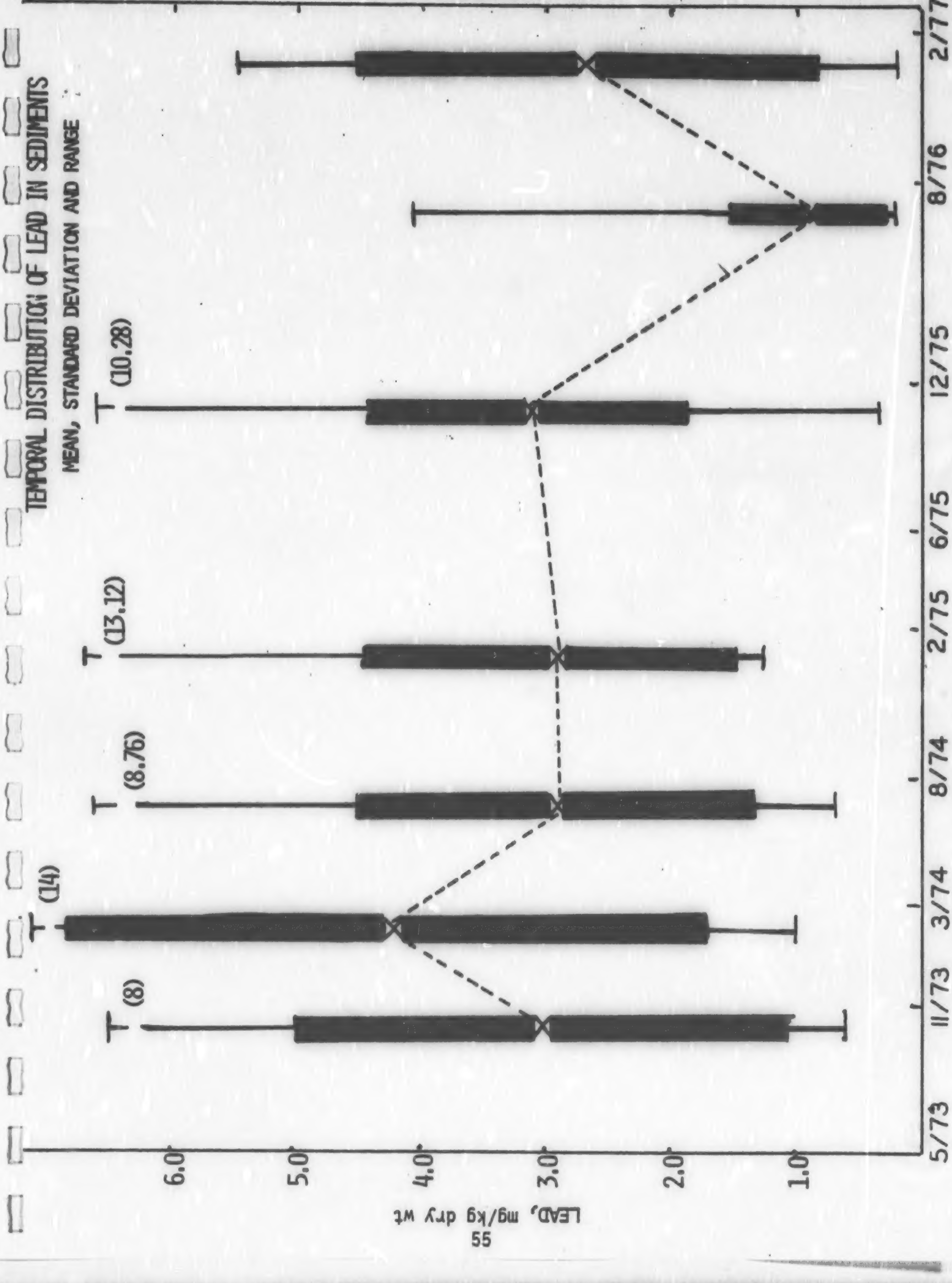
TEMPORAL DISTRIBUTION OF CHROMIUM IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

FIGURE 32



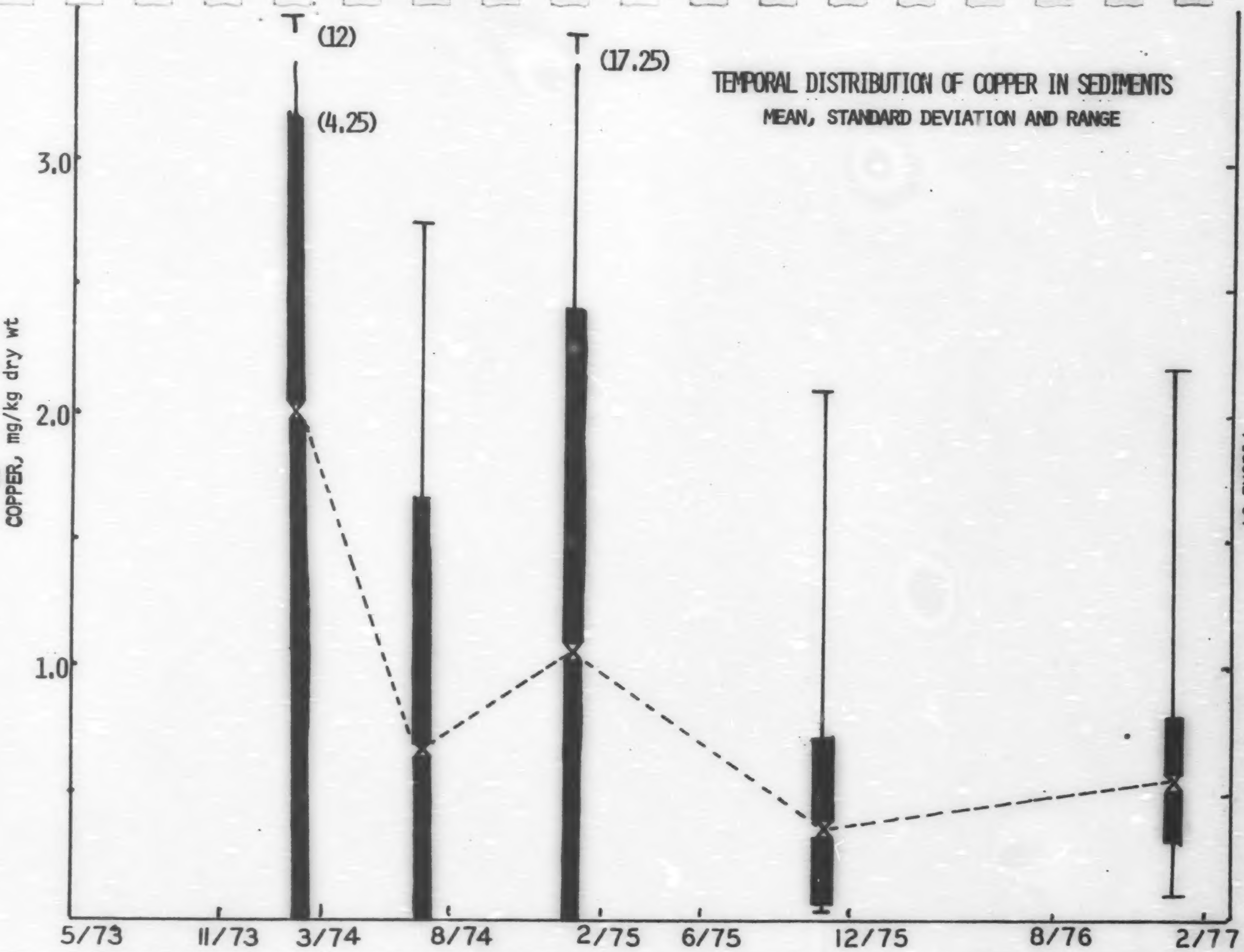
TEMPORAL DISTRIBUTION OF ZINC IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

FIGURE 33



TEMPORAL DISTRIBUTION OF LEAD IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

FIGURE 34



TEMPORAL DISTRIBUTION OF COPPER IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

TOTAL ORGANIC CARBON IN SEDIMENTS

Total organic carbon determinations in sediments were made using similar sampling and statistical treatments as were metals, and were consequently shown with the metals in sediments data. The stations with statistically significant elevations of concentrations of metals were also the stations with statistically significant increases of organic carbon. The interpretation of these data in this context, without qualitative knowledge of the carbon compounds, is difficult. Increased carbon could be derived from sludge deposition, from accumulations of dead organisms from the water column in consistently impacted areas, or from increased populations of opportunistic benthic organisms, among other causes. The association of the high organic carbon concentrations do, however, suggest these are related to ocean dumping activity.

The distribution of TOC as a function of time, Figure 35, indicates ambient concentrations in the order of magnitude of 300 to 800 mg/kg dry wt.

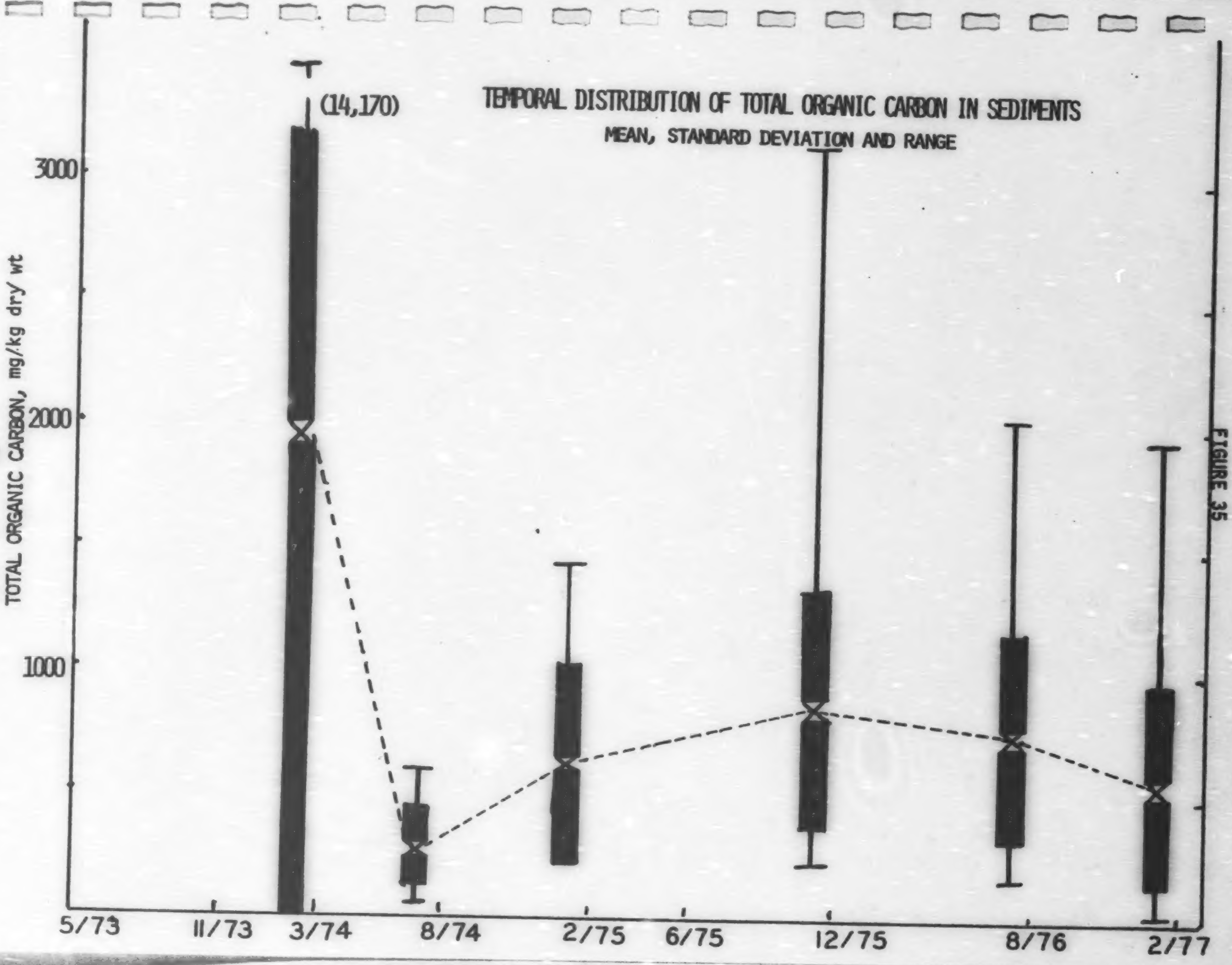


FIGURE 35

TEMPORAL DISTRIBUTION OF TOTAL ORGANIC CARBON IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

ORGANOHALOGENS IN SEDIMENTS

Analyses of the sewage sludge released into this environment showed several organohalogens to be consistently present, consequently checks were made in bottom sediments to determine ambient levels and possible impaction areas. The data for polychlorinated biphenyls (PCB) are shown in Table 9 as Arochlor 1252 and 1254, by station. These data indicate the ambient levels on this shelf environment at a given time, and obviously high concentrations may potentially indicate more direct inputs. These may be related to ocean dumped materials by association with other parameters, such as metals (Lear and Pesch, 1975).

When these data are examined as a function of time (Figure 36), by expressing as mean, standard deviation and range, a cyclical plot results. As these represent the larger scale monitoring grid, it would appear that concentrations of PCB's fluctuate in the entire region with atypically higher concentrations localized in specific areas. Further computations are in progress to examine relationships with salinity differences, reflecting possible inputs from runoff.

Regardless of source, the levels found are potentially deleterious to the marine organisms in the area. Stalling and Mayer (1972) report that levels of 0.94 μg/l archlor 1254 were lethal to immature pink shrimp, and levels of 5 μg/l produced mortalities in the estuarine fish, Lagodon rhomboides and Leiostomus xanthurus. Moreover, these authors report concentration factors in the order of magnitude of 40,000 times.

These data indicate levels of PCB in this Mid-Atlantic Bight in concentrations that can potentially be detrimental to the marine organisms. Ocean dumping activities may contribute locally with even greater impacts.

TABLE 9
PCB (ARCHLOR 1242 and 1254) IN OCEAN SEDIMENTS (ppb)

	Quicksilver 5-73		Fetch 11-73		Ides 3-74		Deep Six 8-74	
Station	1242	1254	1242	1254	1242	1254	1242	1254
1	26	12	5.8	9.1				
2	3	1	ND	ND	33.0	28.7	<0.2	<0.2
5	3	0.9	1.4	2.1				
8	3	0.8	0.5	0.4			<0.2	<0.2
11	3	0.6	1.9	3.1				
13	3	T						
14	2	0.6	2.5	ND			<0.2	1.1
17	23	14	5.2	0.9				
E			0.8	1.7			<0.2	1.7
A			0.3	3.5				
9			5.6	1.7	4.6	4.3		
C			6.1	5.0	1.9	4.7	<0.2	1.4
19					6.5	4.8		
24					49.0/86.0	172.4/560		
26					14.3	11.0	<0.2	1.0
28							<0.2	1.3
33							<0.2	0.9
M- 3								
M- 5								
M- 7								
M- 9								
M-12								
M-14								
C-12								
F								
22								
C- 1								
30								
D- 1								
I-14								
27								
G-52								
G-53								
D								
201								
212								
215								
222								
223								
32								
206								
219								
224								
226								
228								
242								

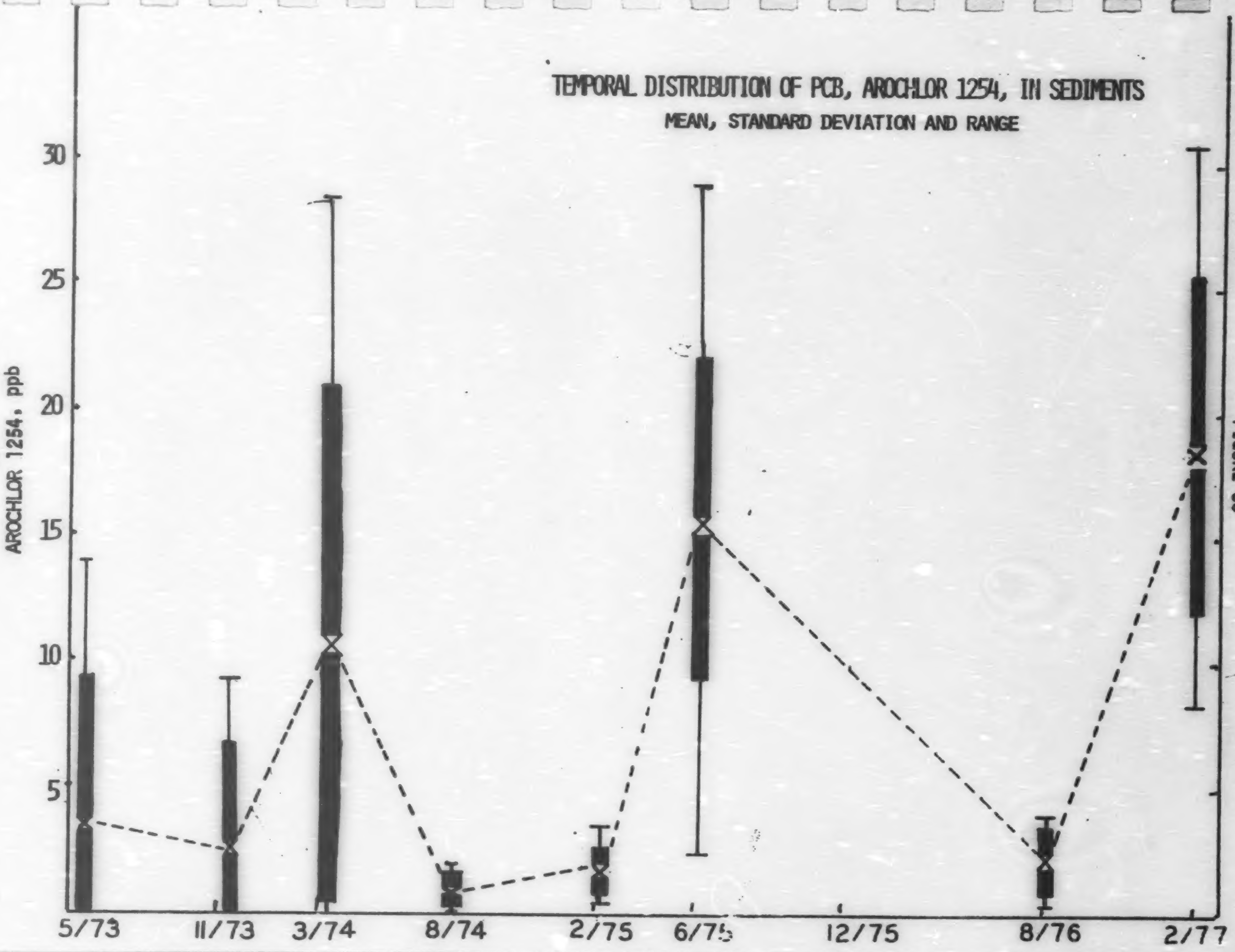
Composite 102, 103, 104, 114, 115, 117
136, 144, 145, 146, 151, 152

TABLE 9 (cont.)

PCB (AROCHLOR 1242 and 1254) IN OCEAN SEDIMENTS (ppb)

Station	Midwatch 2-75	Dragnet 6-75	Touchstone 12-75	Hotspot 8-76	Mogul 2-77
	1254	1254	1254	1254	1254
1					
2	2.52				
5					
8	1.39				
11					
13					
14	0.68	20.5,15.4,13.6			11.1
17	2.19				8.6
E					
A		29.2,14.8, 5.6			31.0
9					
C	2.67				
19					
24		11.1,14.1,16.0			
26					
28					
33	2.08				
M- 3	1.95				
M- 5	1.38				
M- 7	1.88				
M- 9	0.40				
M-12	0.59				
M-14	0.85				
C-12	1.20				
F	1.56	21.6,17.0,20.2			21.2
22	1.57				
C- 1	1.53				
30	2.25				
D- 1	3.33				
I-14	3.58				
27	1.36				
G-52		23.2			
G-53		15.2,22.6			
D		2.4,13.7, 9.6			
201				3.8	
212				3.2	
215				1.8	20.0
222				1.6	
223				0.7	25.4
32					
206					13.3
219					17.6
224					18.8
226					14.6
228					28.7
242					17.5
Composite 102, 103, 104, 114, 115, 117			50.0		
136, 144, 145, 146, 151, 152			80.0		

FIGURE 36



TEMPORAL DISTRIBUTION OF PCB, AROCHLOR 1254, IN SEDIMENTS
MEAN, STANDARD DEVIATION AND RANGE

APPARENT MORTALITIES OF CLAMS

A gross index of apparent mortalities of the mahogany clam, Arctica islandica, is the relative incidence of live, intact clams compared with empty hinged valves, or "clappers". Individual shells, not hinged, are not considered.

The data presented in Figure 37 are the total numbers of live clams and clappers found in duplicate dredge hauls, not percentages. Percent mortalities do not reflect the standing crops of available clams, consequently may bias towards higher indicator numbers.

The low standing crops at Stations A, 32, 22, 23, and 9, all near the 20-fathom isobath, reflect the natural distribution of this organism which was generally found between the 20-and 30-fathom isobaths. Stations F and G-34 are deeper than 30 fathoms and are generally sparser in Arctica.

The data shown indicate apparent recent mortalities on several cruises and at several locations. Stations G-19, C, 14, and 2 show such indications.

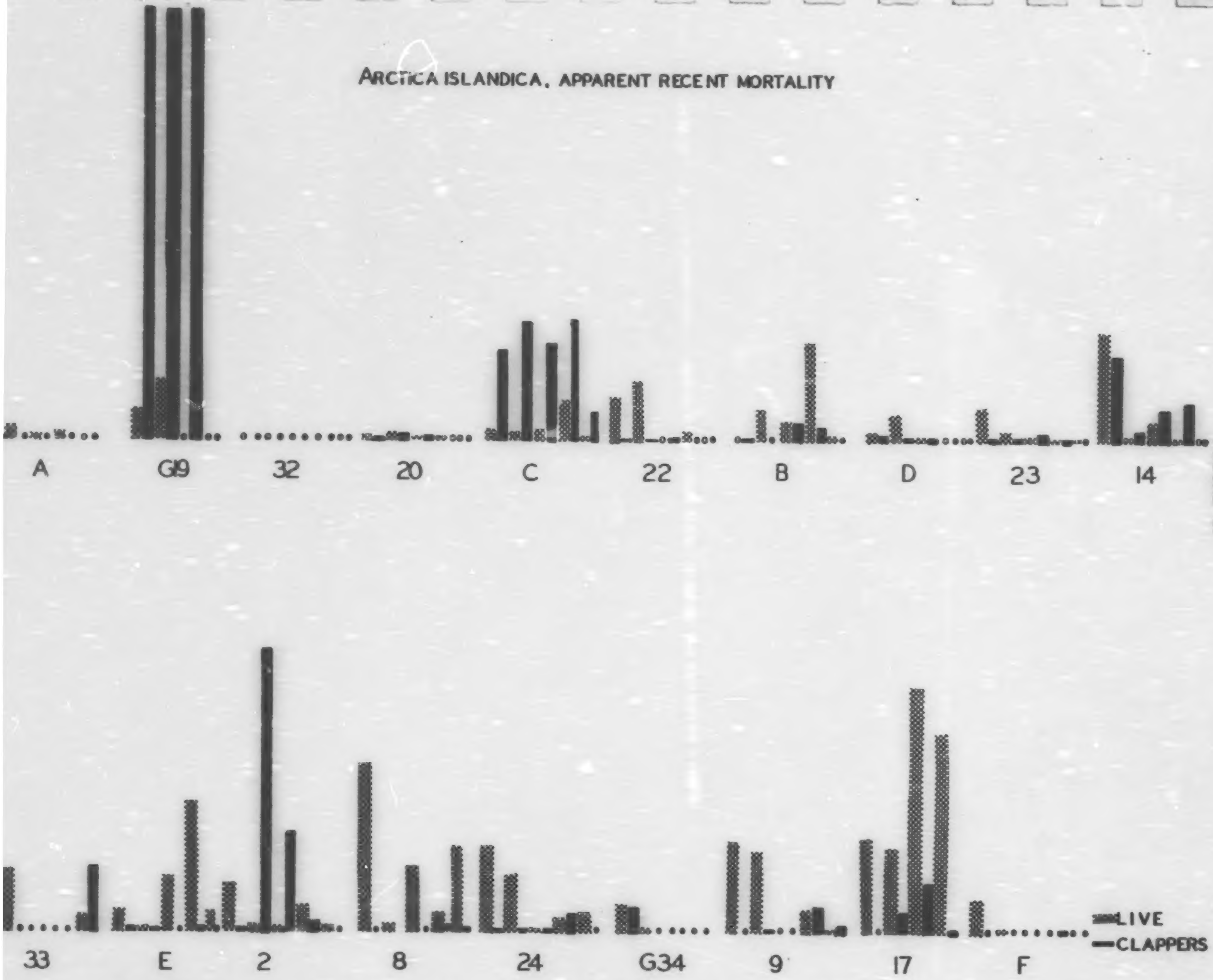
Stations 2 and C are within dumpsites. Station G-19, approximately 20 nautical miles northwest of the dumpsites, has consistently shown significantly high concentrations of metals, indicating an impact. Station 14 is approximately 20 nautical miles east of the dumpsites, and shows indications or mortalities and has shown significantly high concentrations of chromium and lead.

The data show no indications of seasonal mortalities.

These data may also give some indication of the time required for hinge ligaments to rot, whereby "clappers" become individual valves. If the assumption is made that a single incident was responsible for a major mortality at Stations G-19 and 2, a plot of the incidence of "clappers" against time may give an order of magnitude estimate. Such a plot, shown in Figure 38, indicates 12 to 14 months. The apparent increase in numbers of live clams at Station 2 may indicate a repopulation of an area once impacted.

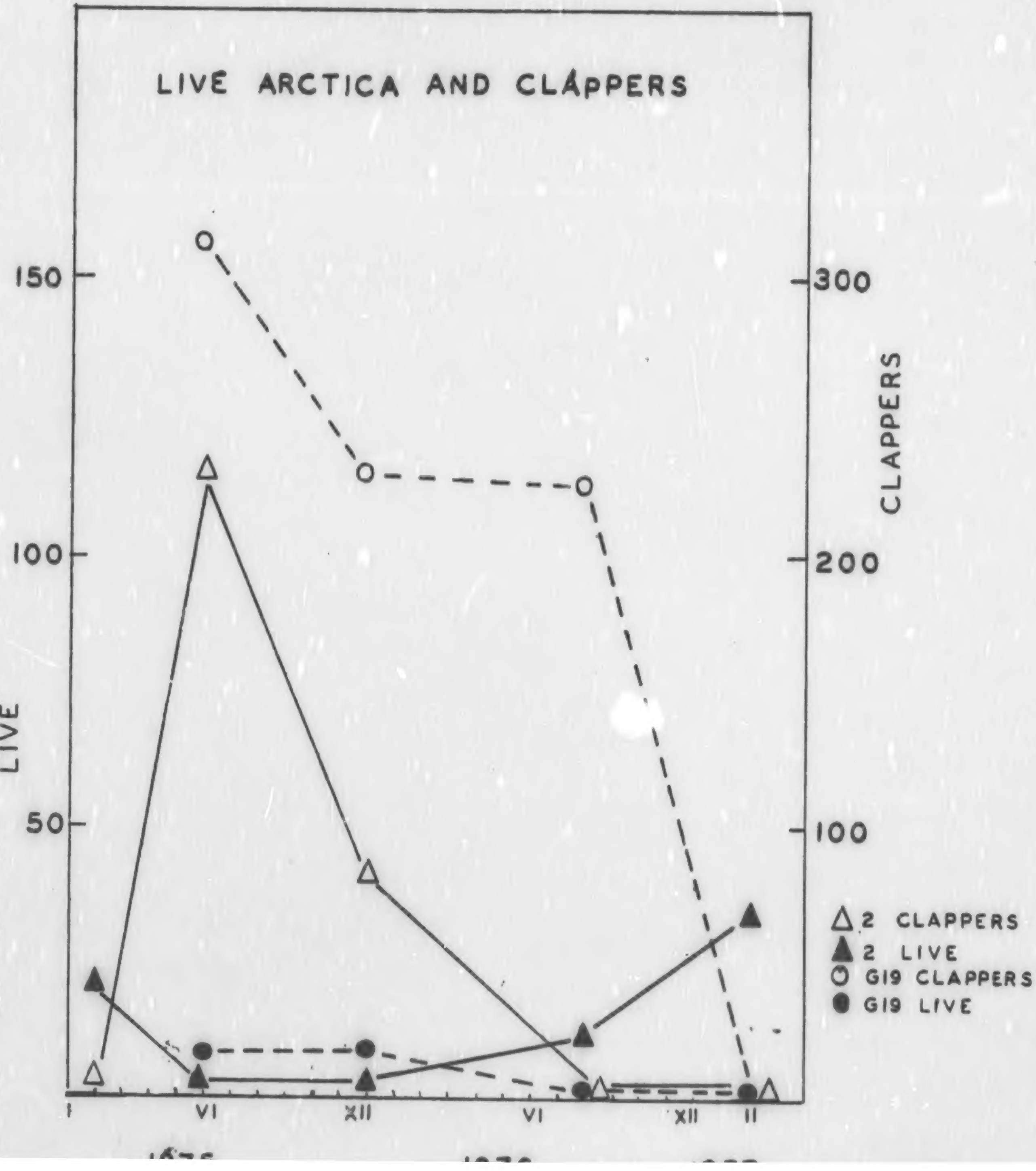
Station G-19 indicates a mortality previous to June 1975, and no evidence of recovery.

FIGURE 37



ARCTICA ISLANDICA, APPARENT RECENT MORTALITY

FIGURE 38


LIVE ARCTICA AND CLAPPERS
LIVE
150
100
50
CLAPPERS
300
200
100
I
VI
XII
VI
XII
II
△ 2 CLAPPERS
▲ 2 LIVE
○ G19 CLAPPERS
● G19 LIVE

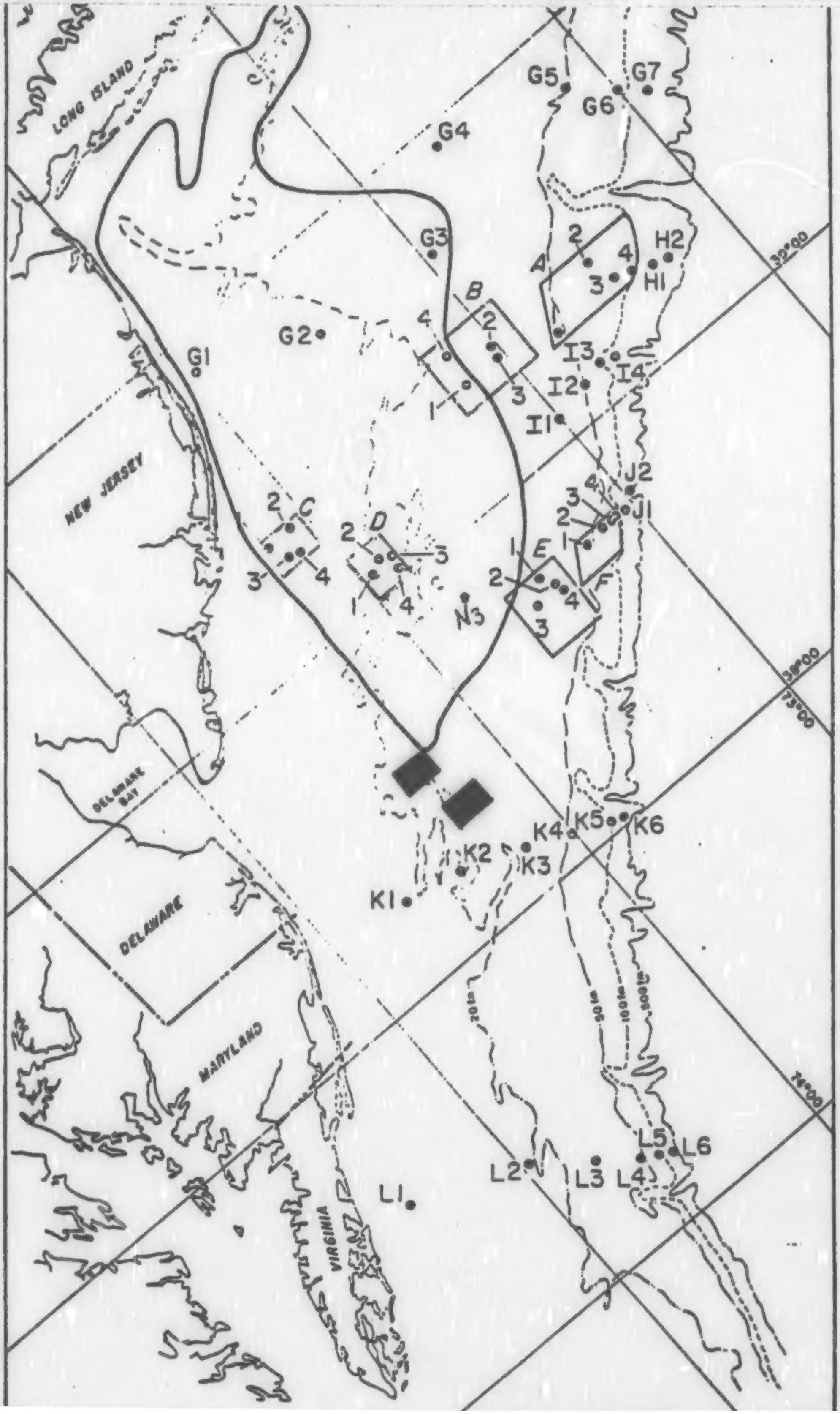
EFFECTS OF ANOXIC CONDITION

A major catastrophic oxygen depletion was noted off the New Jersey coast by other investigators in summer 1976 (Sharp, 1977). This caused major fish kills along some resort communities at the peak of the summer season. This oxygen depletion apparently originated in the apex of the New York Bight, and was at least partially due to pollution from the New York metropolitan area. The extent of this anoxic area was reported to extend nearly to the Delaware-Maryland dumpsite area (Figure 39).

As one function of the February 1977 cruise (Operation Mogul) comparative sampling at stations known to be affected by this condition were occupied, to compare with the stations regularly visited in this program.

Samples of macrobenthos were taken by measured mile with the rocking chair dredge at stations marked C1, D1 and N3. Massive mortality of Arctica clams were found, as indicated by "clappers". There were four live Arctica clams and one small (1-1/2" rock crab, Cancer irroratus, in the sample at Station N3.

In comparison, the stations regularly visited (historical stations) showed patterns of organisms and mortalities as has been regularly experienced in this program. It is concluded, therefore, that the effects of the anoxic area, if present in the study area at all, were not reflected in the macrobenthos sampling. Infauna samples have been archived, waiting analysis.


LONG ISLAND
NEW JERSEY
DELAWARE BAY
DELAWARE
MARYLAND
VIRGINIA
G1
G2
G3
G4
G5
G6
G7
H1
H2
I1
I2
I3
I4
J1
J2
K1
K2
K3
K4
K5
K6
L1
L2
L3
L4
L5
L6
N3
A
B
C
D
E
F
1
2
3
4
39°00
38°00
73°00
74°00
20m
50m
100m
1000m

INTENSIVE GRID MONITORING PROGRAM

An intensive bottom sampling grid, with stations one mile apart, was initiated in December 1975 immediately south of the sewage sludge site. This was occasioned by the detection on earlier cruises of benthic biological community aberrancies at two of the monitoring stations in the area. Areas of atypically discolored sediments were found distributed in this grid sampling area.

The investigation of the intensive sampling area was facilitated by the fact that sediments high in pollutants generally showed an evident "dark" coloration, in contrast to the "clean" sands found elsewhere. To test this hypothesis, chi square analyses were run comparing total organic carbon concentrations greater than and less than the mean of all grid stations, with visual observations noted at time of collection. For the three cruises in December 1975, August 1976, and February 1976, the results of such calculations are shown in Table 10. These data indicate that such field observations can be useful for rapid tentative identification of the areas with higher levels of pollutants.

The distributions of the "clean" and "dark" sediments are shown in Figures 40, 41, and 42 for three cruises. A composite is shown in Figure 43 These data indicate the full areal extent of the discolorations has not yet been found, in spite of increased areas of search on subsequent cruises.

The areas revisited, however, appear to be consistent and persistent. Table 11 shows the findings of stations in common on the three cruises.

With one exception, all areas noted as "dark" on the initial survey remained "dark", while some "clean" areas subsequently became "dark". This indicates this area of impaction is increasing. On the February 1977 cruise, Operation Mogul, two stations at the northwest corner of the grid were found to be layered with "dark" bands interspersed with "clean" sediment, possibly as a result of burial by storm activity.

TABLE 10

Chi-Square Analysis of Dark and Clean Areas with Organic Carbon Concentrations

Touchstone

	TOC > mean	TOC < mean
Dark sediment	30	12
Clean sediment	8	45

$X^2 = 30.98^{**}$

Hotspot

	TOC > mean	TOC < mean
Dark sediment	8	3
Clean sediment	2	16

$X^2 = 11.47^{**}$

Mogul

	TOC > mean	TOC < mean
Dark sediment	10	11
Clean sediment	2	14

$X^2 = 5.11^{*}$

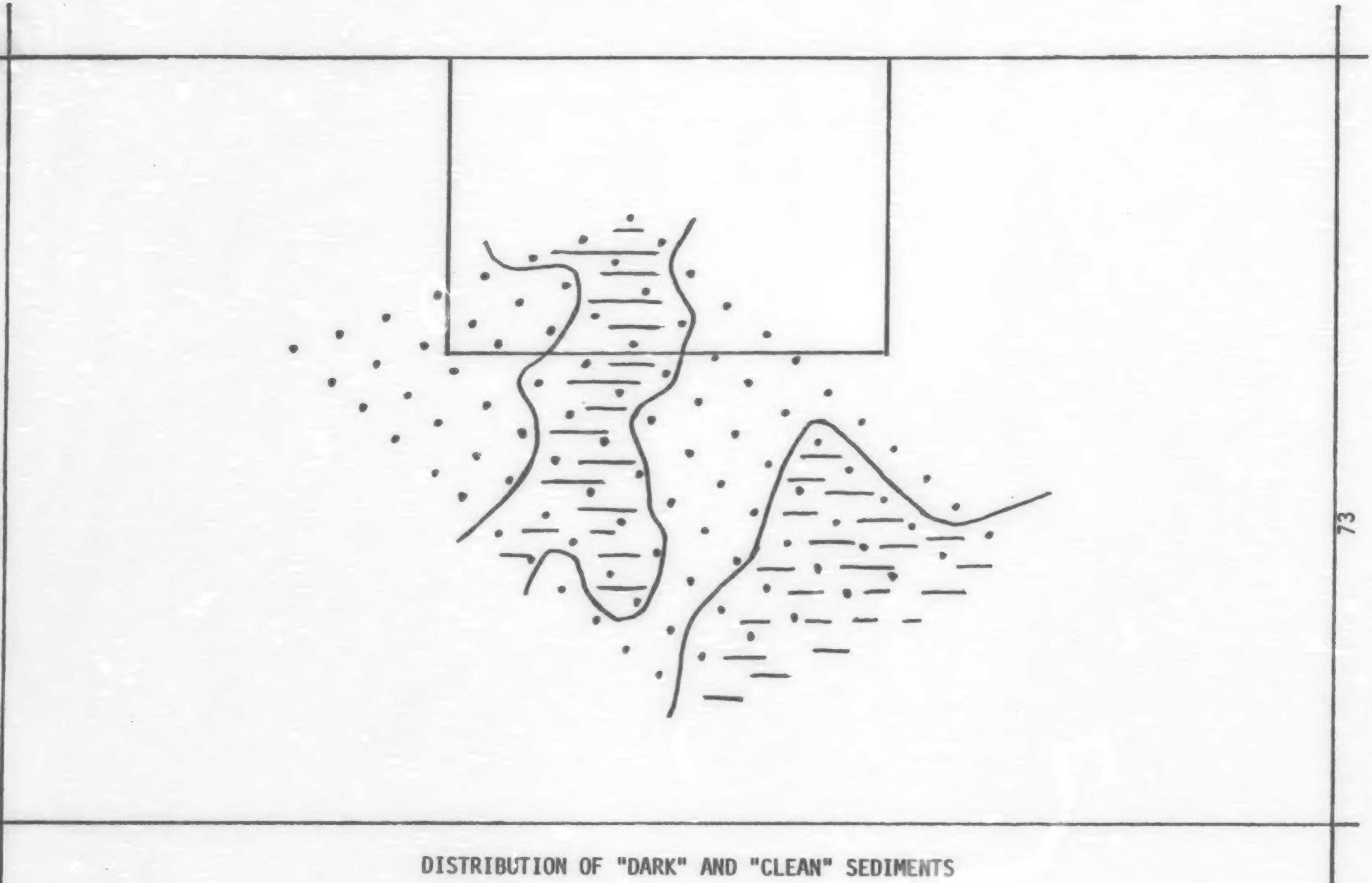
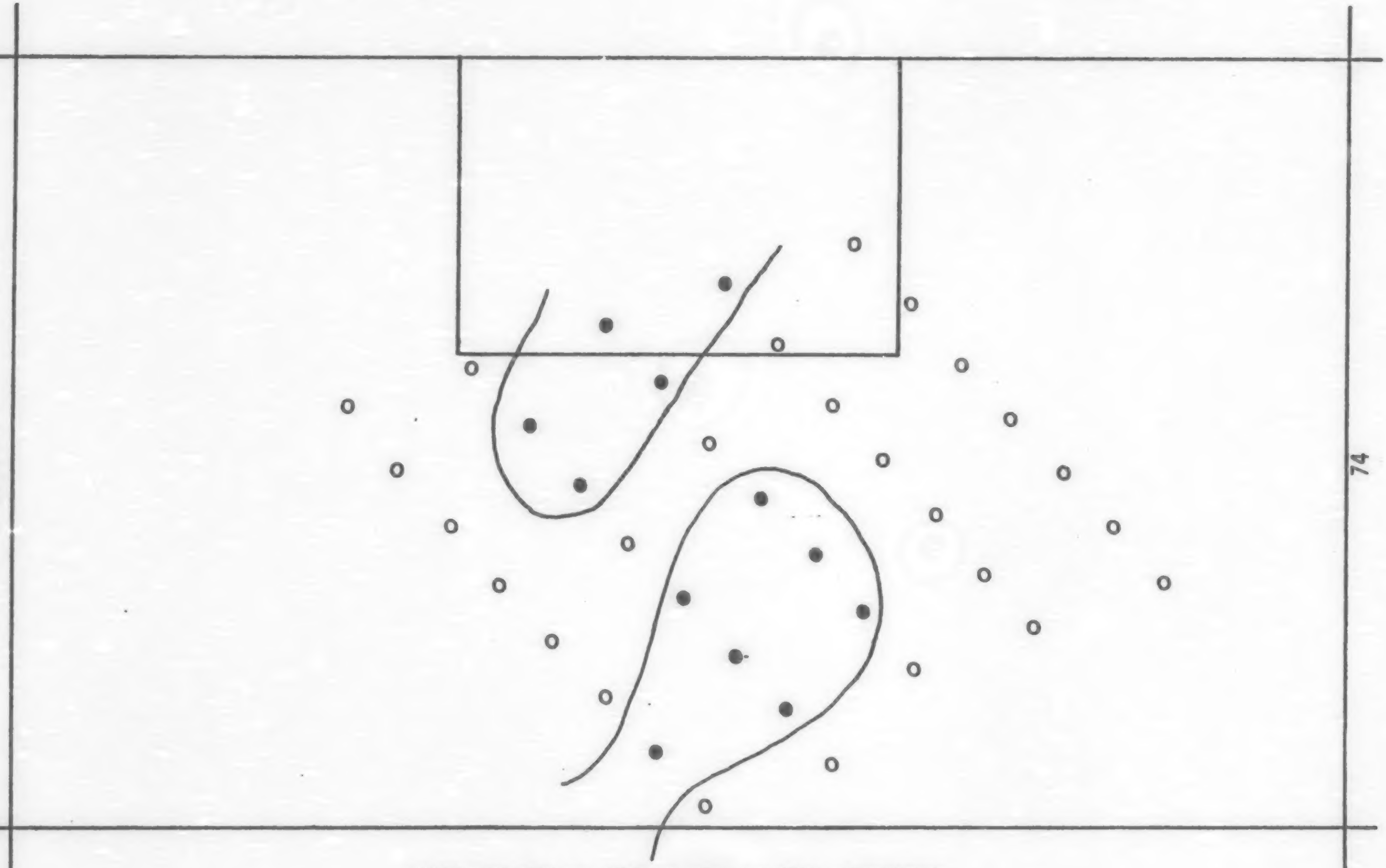


FIGURE 40

DISTRIBUTION OF "DARK" AND "CLEAN" SEDIMENTS

Operation Touchstone
Cruise 75-VI
December 1975

FIGURE 41


74

DISTRIBUTION OF "DARK" AND "CLEAN" SEDIMENTS

Operation Hotspot
Cruise 76-II
August 1976

74° 30'
74° 00'

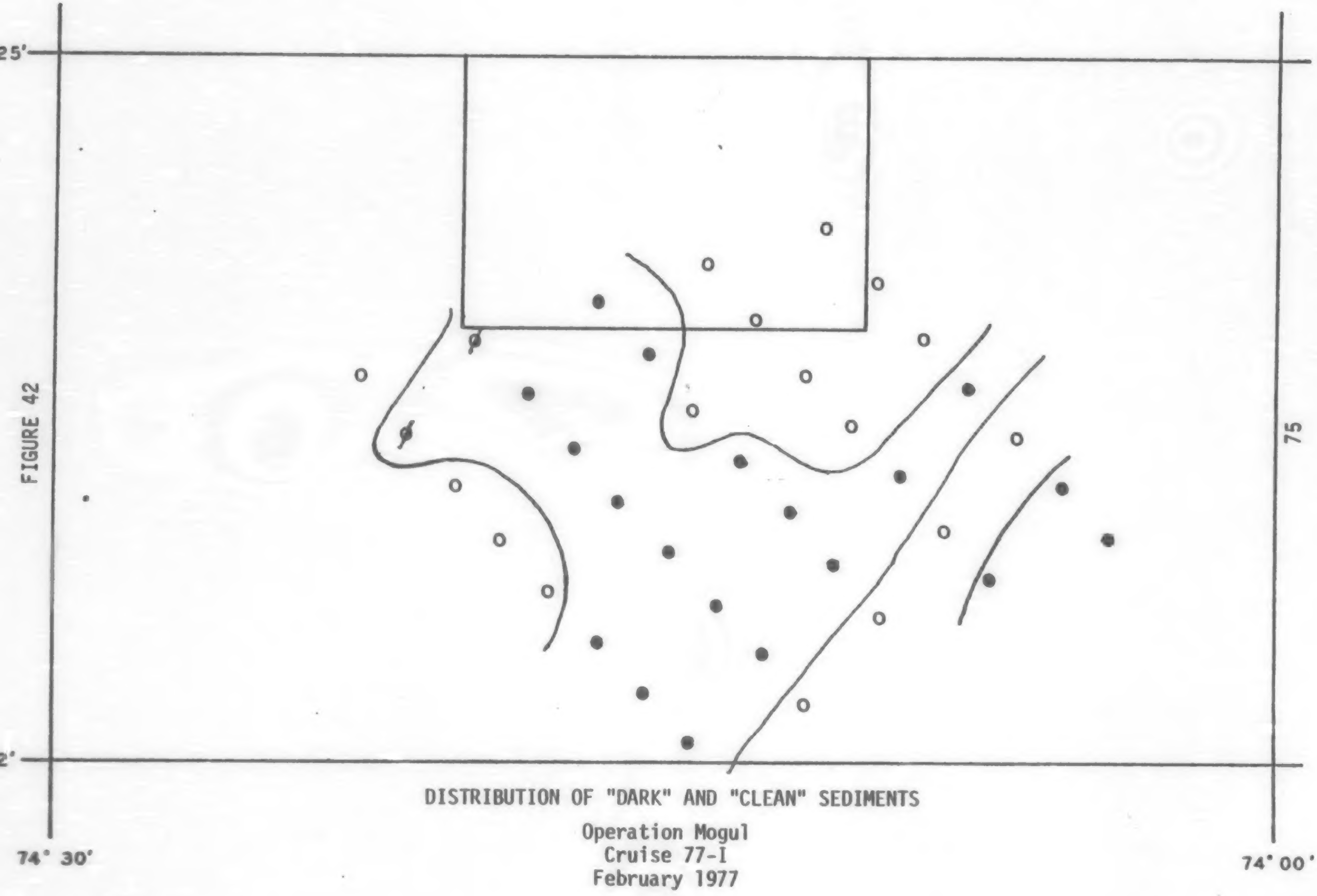

25'
2'
74° 30'
74° 00'

FIGURE 42

DISTRIBUTION OF "DARK" AND "CLEAN" SEDIMENTS

Operation Mogul
Cruise 77-I
February 1977

DISTRIBUTION OF "DARK" AND "CLEAN" SEDIMENTS

Operation Touchstone
Cruise 75-VI
December 1975

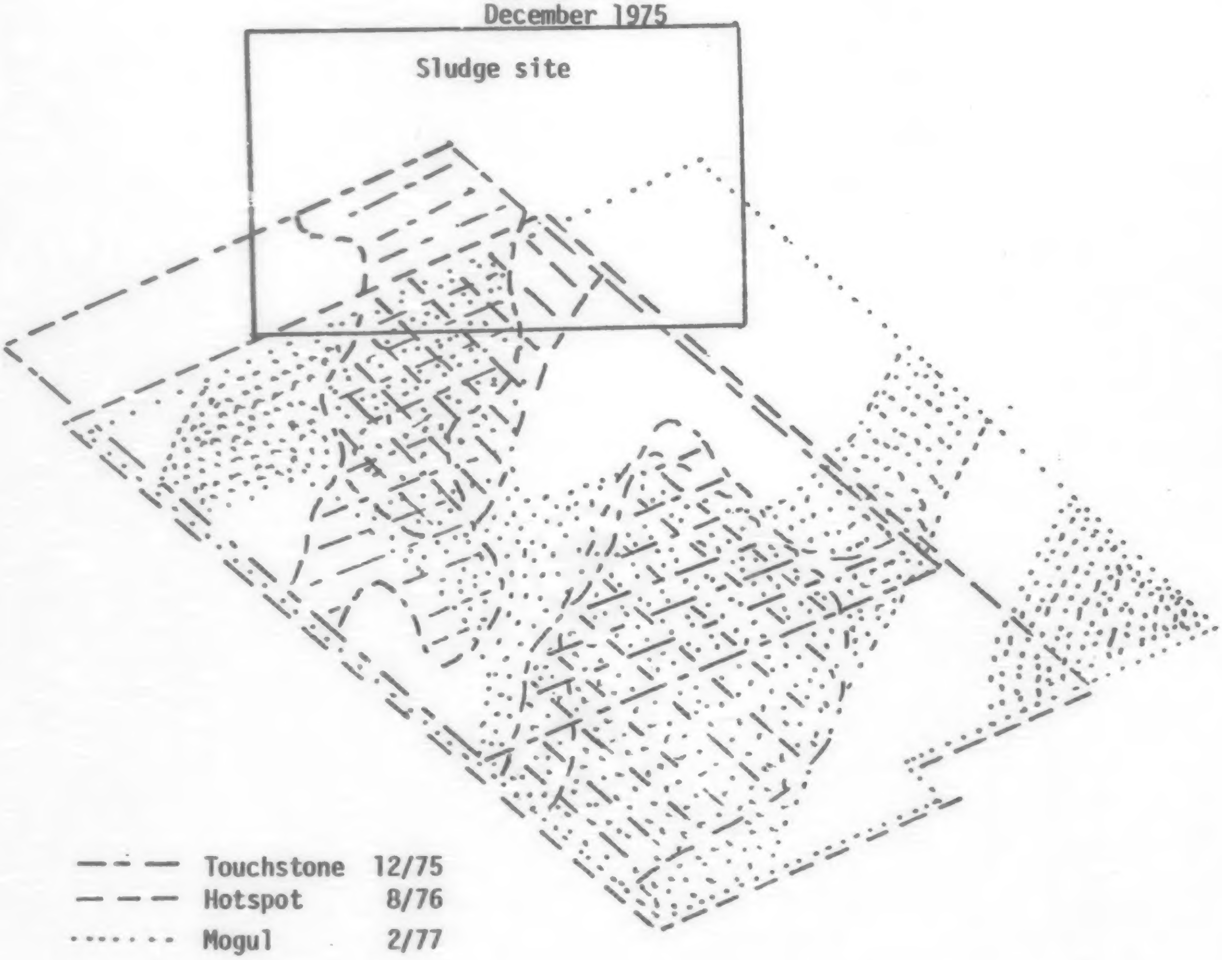

Sludge site
Touchstone 12/75
Hotspot 8/76
Mogul 2/77

FIGURE 43

✓

TABLE 11

Repeat Observations of Dark & Clean Areas
Grid

Loran C	52300	52275	52250	52225
70490	CCC	CCD	DDD	CDC
70500	CCD	DDD	DDD	CCC
70510	C-C	DDD	CCC	CCC
7052C	CCC	DDD	DDD	CCC
70530	CCC	DDD	DDD	CCD
70540	-CD	-DD	-DD	-CC
70550	-DD	-DD	-CC	-CD
70560	-CD	-CC		

C = clean

D = dark

BATHYMETRY

The stability of the high organic carbon areas south of the sludge site led to speculations on why such accumulations occur. Inspection of the available bathymetry on the standard navigational chart of the area showed no apparent depressions coincident with the organic carbon areas. Previous bathymetry by EPA on the first cruise in May 1973, limited to the boundaries of the release site, showed no apparent depressions. A chart, "Bathymetry of the Virginia Sea," by V. Goldsmith and C. H. Sutton at the Virginia Institute of Marine Science, shows a small basin at approximately the southern boundary of the sewage sludge site, but insufficient relief to account for the configurations found.

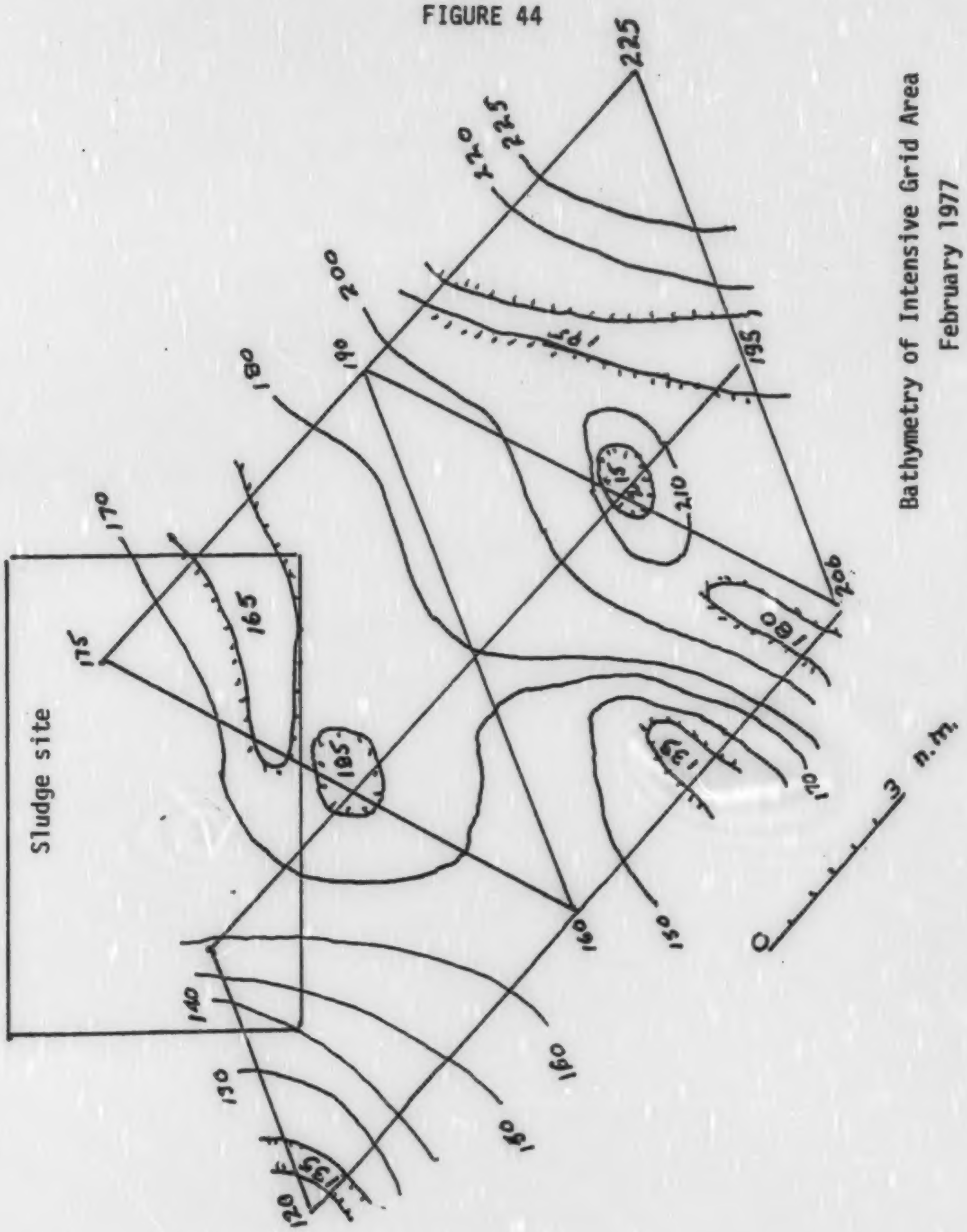
One facet of the February 1977 (Operation Mogul) cruise was a bathymetric survey of the area to the south of the sludge site, using the recording depth finder available on the U.S. Coast Guard Cutter ALERT. The resultant fathograms were plotted at approximately three-hundred yard intervals. This interpretation resulted in a contoured plot of the intensive grid area with very subtle relief features evident (Figure 44). Several features not evident on other charts were discernable, but consistent with the known northeast-southwest ridge and swale topography characteristic of the Mid-Atlantic shelf.

The northeast corner of the area showed a fairly gentle slope, 40 feet over 5 miles, leading to a basin-like depression, with relief of 15 feet over approximately 1.5 mi. Small ridges and troughs were e evident on the northeast and southwest sides, and another minor depression suggested towards the southern end of the area. The southeast corner seemed to grade off towards a known steep slope or scarp.

Superimposition of the distribution of the organic carbon areas on a chart with the derived geomorphologic features indicates that the flat, gently sloped or depressed areas are higher in organic carbon, and the slight ridges are generally cleaner. This suggests that the materials are not so much trapped in depressions as the ridges are swept clean by the current regimes. The implications here are that, while organic carbon areas with concomitant metallic pollutants have been consistently found in characteristic distribution in this area, the usual hydraulic regime is sufficiently energetic to keep the ridges cleaned off. The converse, of accumulation in these minor depressions, must be viewed with caution, however, for high energy events such as storm surges may be capable of redistributing these materials. That such case may be true are observations of intermediate layering of dark bands with clean bands of sediment in the sampler, found on the slope on the northwest side of the area during the past cruise. This indicates a cataclysmic activity, rather than biological reworking. As this area is described as geologically non-depositional, but as a palimpsest, the strength of evidence to date would be insufficient to conclude the organic carbon area is stabilized in the locations so far described.

If further materials were added to the area, it can be hypothesized that the organic carbon area would increase to the seaward, less energetic side.

FIGURE 44



225
220
225
200
190
195
195
180
170
175
165
15
210
206
180
185
139
170
160
150
140
160
130
150
120
135
Sludge site
0
3
n.m.

Bathymetry of Intensive Grid Area
February 1977
Depths in Feet

METALS AND TOTAL ORGANIC CARBON IN SEDIMENTS - INTENSIVE GRID AREA

The distribution of metals and organic carbon in the intensive grid area was determined statistically using Duncan's new multiple range test. This procedure objectively selects the stations statistically related at a selected level, in this case the 0.05 probability level. The data are shown in tabular form (Tables 12 through 26) and plotted in Figures 45 through 66 with the statistically highest subsets encircled by broken lines. Cadmium is shown on chart only, for there were too many indeterminate values for statistical comparison.

These plots show the distribution of the contaminant organic carbon and metals fall statistically into similar patterns, indication of a common source. As these materials are major components of the sludge, as shown by analysis of the barged materials, it can be concluded that this was an accumulative area for such dumped materials.

TABLE 12

METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations

TOC

Station	Mean
102	380
115	405
117	410
114	426
104	440
138	450
179	453
103	460
133	463
161	463
196	470
180	493
134	506
111	510
121	520
112	530
178	533
162	566
135	570
139	585
140	586
173	600
101	613
106	636
131	640
130	650
177	653
182	663
125	670
168	676
132	686
116	710
155	713
181	720
188	733
113	743
107	746
142	750
105	750
165	753
148	756
153	760
143	766
119	773
184	775
120	796
170	810
195	826
147	850
167	850
174	860
160	866
163	896
156	930
190	956
164	963
141	980
189	1006
169	1023
154	1045
172	1053
191	1076
149	1080
157	1105
124	1120
183	1136
108	1136
187	1160
193	1163
194	1170
166	1170
158	1190
185	1230
186	1233
192	1233
159	1240
171	1333
137	1363
175	1376
176	1385
109	1396
110	1436
118	1450
128	1470
150	1546
123	1605
122	1610
126	1720
129	1956
127	2226
152	2290
136	2333
151	2396
144	2556
145	2570
146	2873

ANOVA

	df	sos	ms	F
Between	95	83104560	874784	8.0**
Within	183	17915833	97900	
Total	278	101020394		

TABLE 13
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations
Cr

Station	Mean
142	0.98
196	0.99
105	1.02
101	1.08
115	1.13
103	1.22
125	1.29
139	1.29
140	1.29
132	1.31
104	1.36
143	1.37
124	1.40
112	1.43
133	1.46
120	1.48
117	1.51
138	1.53
106	1.56
131	1.58
113	1.60
180	1.67
160	1.71
134	1.75
153	1.75
130	1.79
119	1.80
116	1.80
114	1.86
102	1.89
135	1.89
154	1.91
126	1.92
155	1.94
165	1.94
141	1.96
147	1.97
172	2.07
189	2.09
156	2.18
149	2.19
177	2.20
121	2.21
181	2.24
162	2.26
159	2.29
178	2.32
107	2.37
111	2.40
194	2.43
182	2.45

Station	Mean
137	2.50
167	2.54
123	2.56
168	2.58
170	2.58
152	2.60
148	2.63
195	2.66
118	2.66
169	2.68
179	2.69
158	2.73
174	2.76
193	2.82
173	2.83
127	2.88
150	2.92
122	2.93
171	2.96
188	2.96
129	2.99
157	3.01
190	3.08
186	3.12
183	3.18
144	3.22
166	3.30
163	3.33
151	3.38
110	3.39
192	3.43
184	3.45
187	3.53
136	3.55
175	3.55
108	3.56
109	3.65
176	3.67
145	3.74
128	3.92
191	4.14
161	4.22
164	4.53
146	4.77

ANOVA

	df	sos	ms	F
Between	94	221.32	2.35	4.29**
Within	187	102.65	0.549	
Total	281	323.98		

TABLE 14
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations
Zn

Station	Mean
194	0.92
128	1.35
123	1.71
196	1.89
117	2.21
105	2.27
114	2.37
101	2.40
152	2.40
161	2.42
140	2.45
120	2.47
139	2.64
180	2.65
132	2.67
142	2.69
125	2.74
143	2.77
118	2.84
115	2.86
153	2.94
119	2.96
165	3.00
131	3.01
182	3.02
113	3.09
133	3.14
154	3.24
138	3.24
134	3.32
169	3.33
167	3.35
136	3.35
168	3.36
147	3.42
127	3.49
135	3.50
106	3.53
148	3.55
149	3.65
103	3.60
177	3.66
155	3.68
160	3.68
102	3.70
112	3.79
156	3.91
124	4.02
121	4.07
162	4.09
116	4.23
172	4.25
188	4.32
111	4.32
178	4.47
181	4.48
126	4.50
189	4.65
130	4.84
173	4.89
141	4.92
159	5.17
195	5.19
137	5.34
107	5.40
104	5.50
179	5.63
170	5.67
158	5.67
157	5.68
184	5.89
190	6.07
183	6.60
187	6.79
150	6.90
191	6.96
171	6.98
166	7.04
122	7.11
174	7.22
192	7.35
175	7.41
144	7.78
186	7.79
185	8.00
151	8.04
163	8.08
176	8.11
109	8.31
193	8.34
129	8.35
145	8.52
164	9.05
146	9.31
108	9.42
110	9.73

ANOVA

	df	sos	ms	F
Between	95	1285.13	13.53	5.76**
Within	187	439.12	2.35	
Total	282	1724.25		

TABLE 15
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations
Iron

Station	Mean
104	720
105	732
101	862
180	865
117	868
103	893
196	896
115	933
106	966
118	1045
142	1055
113	1117
140	1120
161	1140
139	1146
102	1156
132	1156
114	1159
120	1199
112	1222
116	1231
124	1233
147	1244
143	1267
165	1287
160	1303
126	1329
138	1354
119	1366
153	1393
107	1400
182	1403
133	1443
125	1444
141	1483
134	1497
188	1497
131	1511
181	1539
111	1574
177	1586
154	1636
152	1654
156	1661
189	1669
155	1674
148	1685
167	1711
184	1726
178	1808
168	1823

Station	Mean
162	1823
135	1842
121	1859
179	1866
172	1888
187	1892
169	1913
109	1939
183	1941
195	1983
149	2025
158	2034
159	2045
190	2056
186	2058
173	2064
130	2071
123	2130
150	2134
170	2180
110	2256
137	2262
185	2265
191	2267
144	2270
108	2310
174	2377
151	2404
136	2408
192	2439
157	2475
193	2494
129	2503
122	2535
127	2617
166	2740
146	2749
194	2771
145	2822
171	2826
175	2935
164	3072
163	3135
176	3308
128	3331

ANOVA

	df	sos	ms	F
Between	95	111868617	1177564	9.7**
Within	187	22627719	121004	
Total	282	134496336		

TABLE 16
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations
Cu

Station	Mean
165	.05
167	.05
115	.09
180	.09
117	.11
161	.12
183	.14
120	.15
130	.17
196	.18
168	.19
101	.20
189	.21
118	.23
125	.23
114	.23
153	.23
148	.24
182	.26
184	.26
121	.27
134	.28
150	.28
142	.29
131	.30
135	.30
119	.30
162	.30
139	.31
112	.32
103	.33
132	.33
154	.34
147	.35
140	.35
188	.36
143	.36
138	.38
149	.39
102	.40
141	.41
116	.42
124	.42
176	.42
177	.42
133	.42
178	.42
156	.45
157	.45

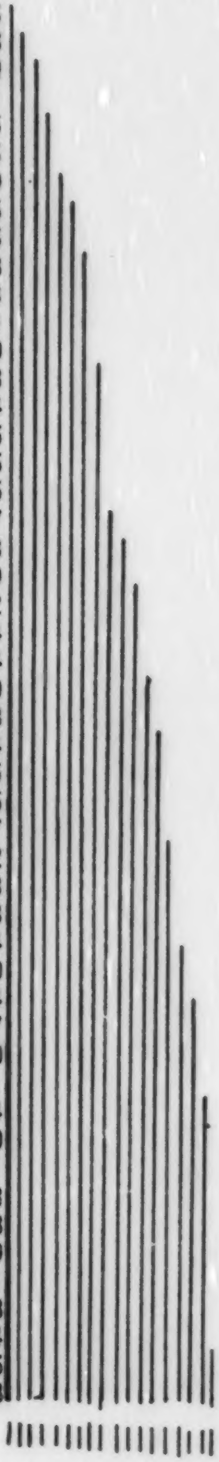
Station	Mean
172	.46
155	.46
113	.47
111	.48
195	.48
152	.49
160	.49
104	.49
105	.50
171	.52
169	.52
181	.53
190	.56
158	.56
107	.57
185	.61
106	.62
170	.63
159	.63
187	.70
174	.71
179	.72
194	.72
173	.74
126	.76
163	.77
192	.78
151	.79
129	.79
166	.80
193	.85
191	.88
109	.95
123	.96
175	.98
164	1.02
144	1.06
137	1.07
110	1.07
108	1.08
145	1.12
146	1.15
122	1.19
127	1.20
186	1.23
128	1.85
136	1.96

ANOVA

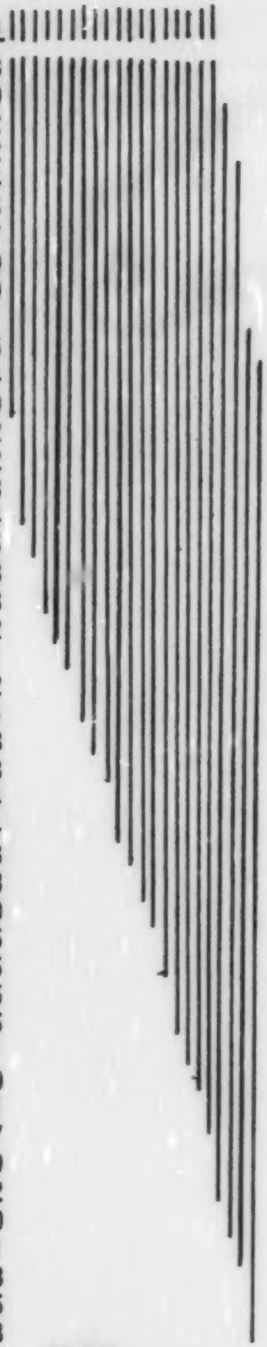
	df	sos	ms	F
Between	95	56.74	0.5972	7.35**
Within	177	14.37	0.081	
Total	272	71.11		

TABLE 17
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations
Ni

Station	Mean
117	0.15
149	0.28
133	0.39
119	0.41
120	0.45
105	0.46
104	0.49
113	0.55
101	0.55
134	0.58
116	0.58
114	0.59
118	0.60
130	0.63
132	0.64
106	0.65
110	0.65
115	0.65
138	0.67
112	0.68
103	0.69
165	0.72
180	0.74
139	0.74
131	0.80
142	0.83
196	0.84
124	0.86
147	0.86
121	0.87
140	0.92
102	0.93
111	0.93
125	0.94
152	1.00
169	1.04
141	1.07
154	1.10
148	1.11
161	1.14
160	1.20
155	1.21
167	1.23
182	1.23
177	1.29
172	1.31
107	1.33
126	1.34
162	1.35
143	1.38



Station	Mean
183	1.38
135	1.40
150	1.52
168	1.52
184	1.54
159	1.56
181	1.57
156	1.59
173	1.59
108	1.61
158	1.66
195	1.74
188	1.79
170	1.82
189	1.82
178	1.83
137	1.94
164	2.05
157	2.08
171	2.08
190	2.12
145	2.21
123	2.22
129	2.24
146	2.28
122	2.33
127	2.34
166	2.34
144	2.38
194	2.43
186	2.50
109	2.55
175	2.56
192	2.65
187	2.66
174	2.71
185	2.80
179	3.01
163	3.07
128	3.09
191	3.12
151	3.20
153	3.31
136	3.33
176	3.35
193	3.38



ANOVA

	df	sos	ms	F
Between	95	205.03	2.16	3.17**
Within	186	126.66	0.68	
Total	281	331.69		

TABLE 18
METALS IN SEDIMENTS
Operation Touchstone - Cruise 75-VI
Duncan's Multiple Range Test
Grid Stations

Station	Mean
117	0.74
196	1.02
105	1.18
180	1.25
118	1.43
101	1.56
111	1.68
135	1.79
182	1.81
113	1.91
120	1.92
114	1.93
115	1.93
165	1.96
119	2.01
110	2.12
104	2.23
112	2.30
102	2.34
167	2.43
161	2.45
106	2.50
132	2.55
125	2.56
134	2.57
103	2.57
189	2.63
143	2.66
154	2.67
140	2.68
133	2.73
181	2.73
138	2.76
153	2.84
139	2.89
142	2.99
124	3.01
116	3.02
160	3.09
192	3.10
177	3.11
188	3.12
195	3.16
183	3.19
155	3.24
184	3.28
130	3.42
123	3.45
170	3.45
121	3.48
107	3.53
131	3.77

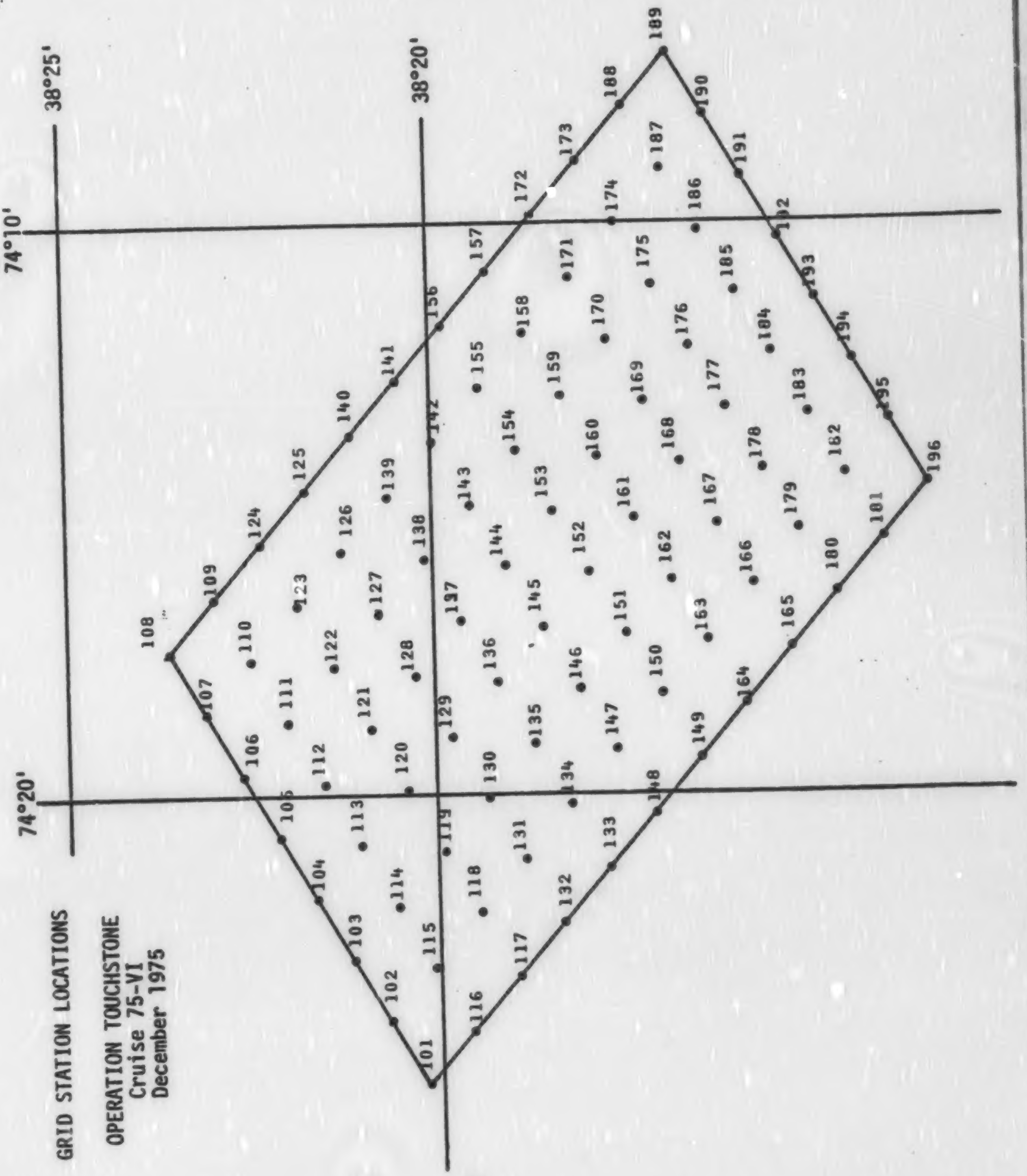
Pb

Station	Mean
168	3.79
179	3.88
169	3.91
172	3.93
158	3.94
178	4.06
190	4.06
191	4.09
156	4.11
126	4.11
149	4.22
162	4.40
148	4.49
147	4.51
144	4.53
157	4.53
173	4.54
174	4.56
193	4.60
108	4.86
187	5.08
159	5.08
129	5.10
194	5.14
141	5.15
145	5.19
176	5.22
175	5.24
171	5.25
151	5.29
127	5.38
163	5.39
122	5.53
109	5.57
137	5.73
186	5.73
152	5.75
150	5.93
166	5.96
146	6.55
128	6.89
136	7.02
164	7.59
185	10.28

ANOVA

	df	sos	ms	F
Between	95	723.54	7.61	2.26**
Within	187	628.65	3.36	
Total	282	1352.19		

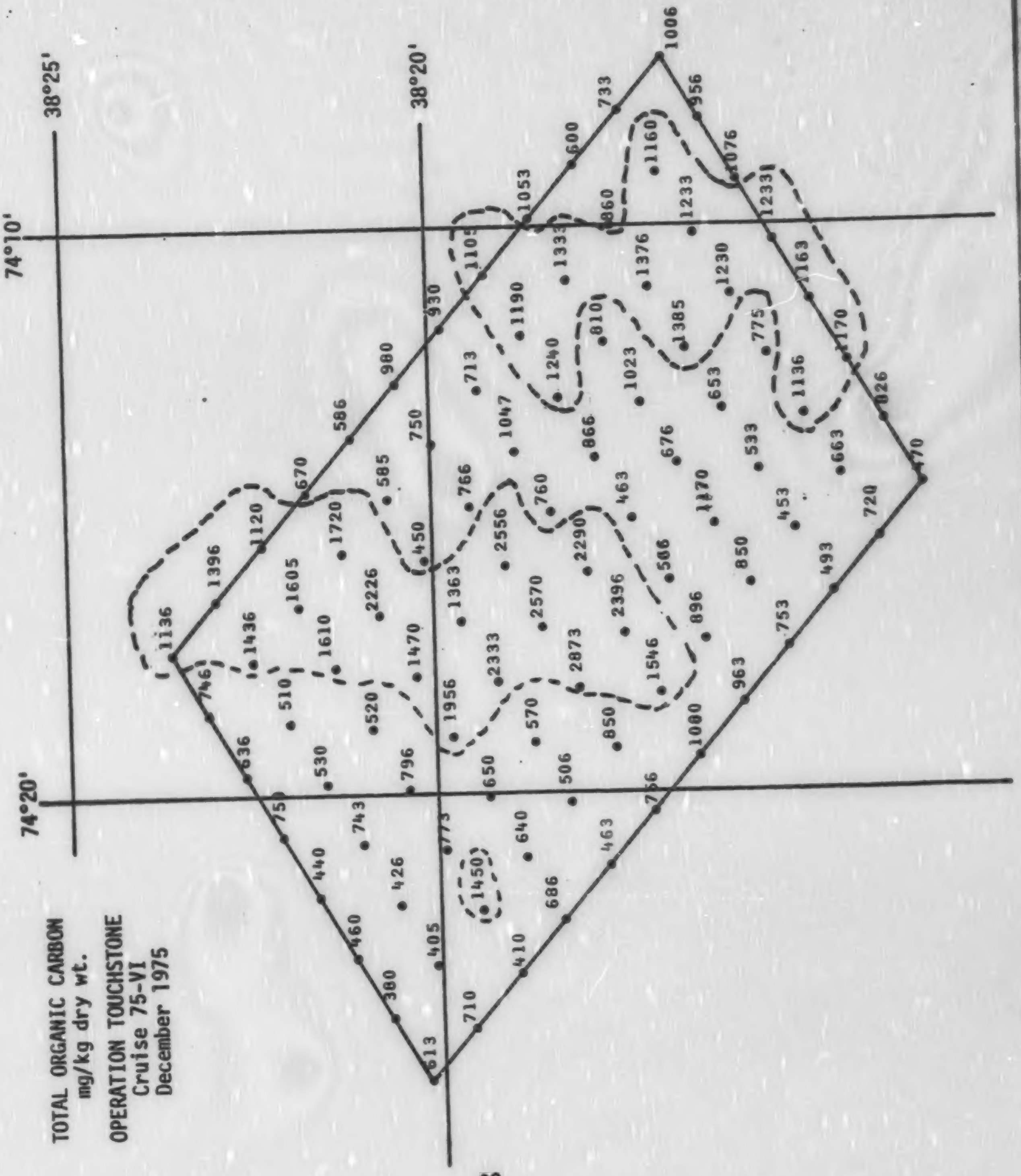
FIGURE 45


GRID STATION LOCATIONS

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

38°25'
38°20'
74°10'
74°20'
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196

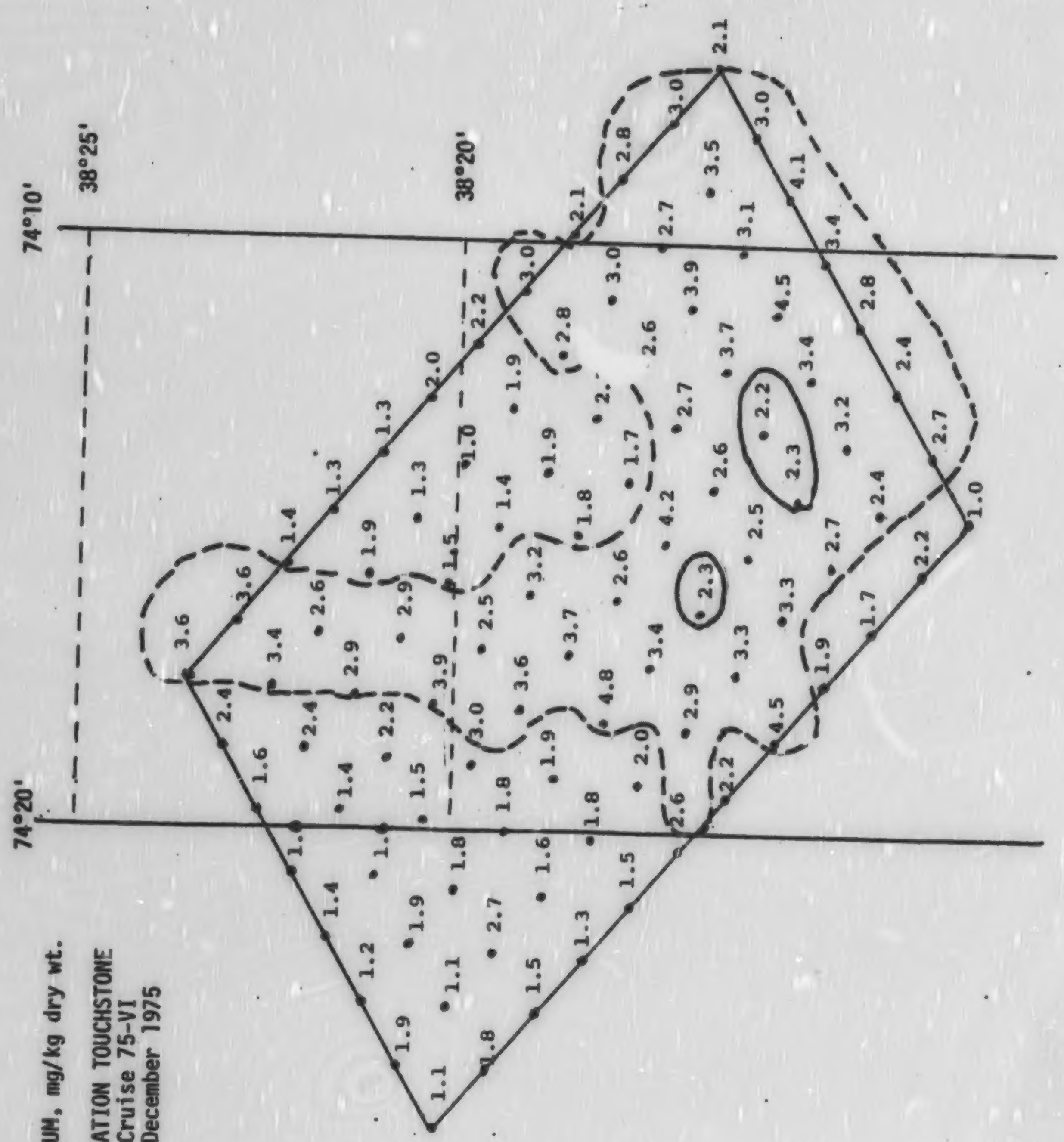
FIGURE 46


38°25'
38°20'
74°10'
74°20'
1136
1396
1120
670
586
980
930
1105
1053
600
733
1006
956
1076
1233
1163
1170
1026
1470
720
493
753
963
1080
756
463
686
410
710
613
380
460
440
750
836
746
1436
1605
1720
585
750
713
1190
1333
860
1160
1233
1376
1230
775
1136
663
453
533
653
1385
1023
810
1240
1047
766
450
2226
1610
510
1470
520
530
796
743
426
405
1450
773
650
1956
1363
2556
760
866
676
1170
850
586
463
2290
2333
2570
2873
2396
1546
896
570
850
506
640

TOTAL ORGANIC CARBON
mg/kg dry wt.

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

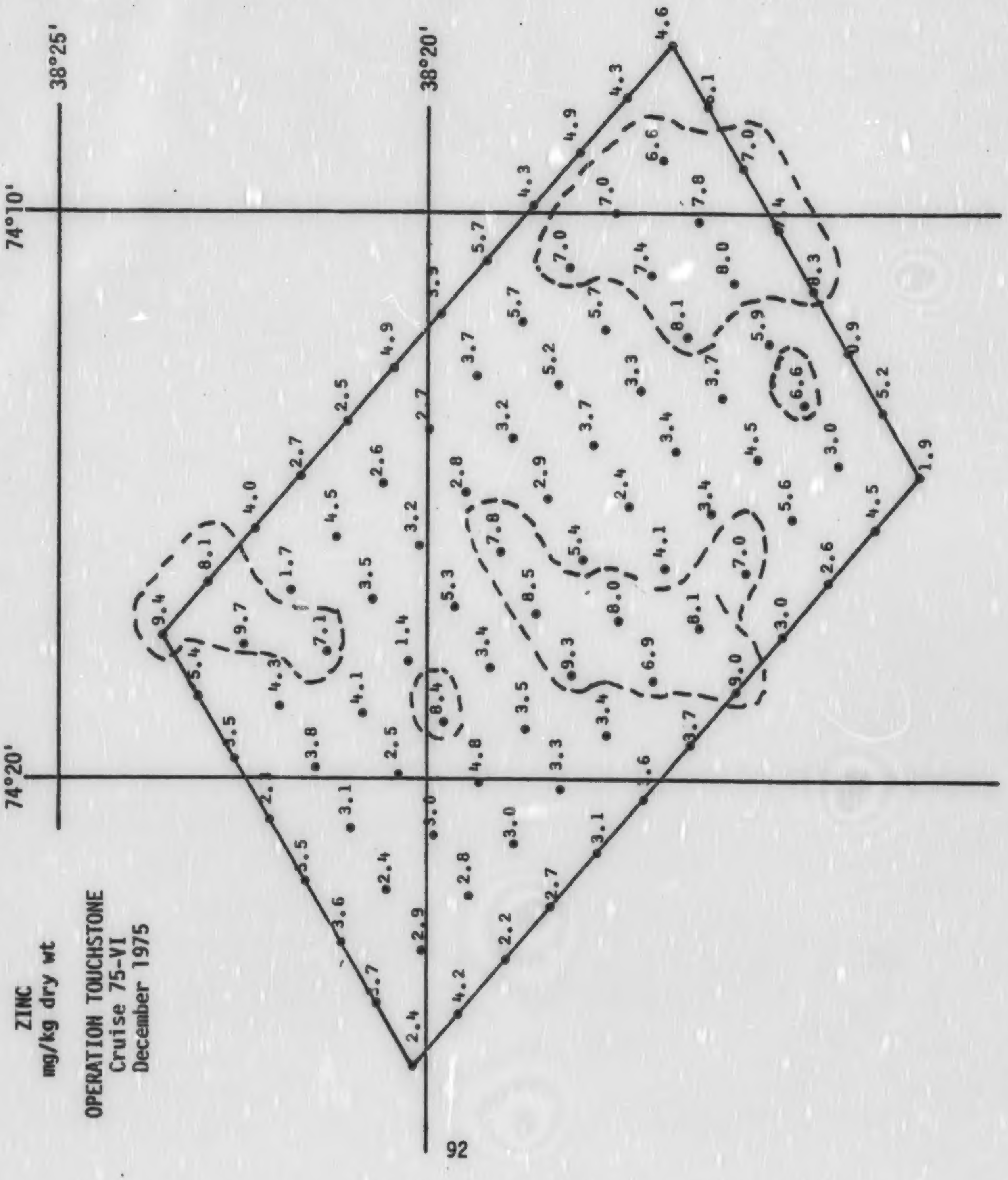
FIGURE 47


74°10'
74°20'
38°25'
38°20'
3.6
2.4
3.6
3.4
1.6
1.4
2.6
2.4
1.4
1.
1.3
1.9
2.9
2.2
1.5
1.
1.4
1.9
1.3
1.3
2.9
3.9
1.5
1.8
1.2
1.9
1.9
2.0
1.5
1.0
2.5
3.0
1.8
1.1
2.7
1.1
1.8
2.2
1.9
1.4
3.2
3.6
1.9
1.6
1.5
1.8
3.0
2.8
1.9
1.8
3.7
4.8
1.8
1.3
2.
2.6
1.7
4.2
3.4
2.0
1.5
2.1
3.0
2.6
2.7
2.3
2.9
2.6
2.8
2.7
3.9
3.7
2.6
2.5
3.3
2.2
3.0
3.5
3.1
4.5
3.4
2.2
2.3
3.3
4.5
2.1
3.0
4.1
3.4
2.8
2.4
3.2
2.4
2.7
1.9
1.7
2.2
2.7
1.0

CHROMIUM, mg/kg dry wt.

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

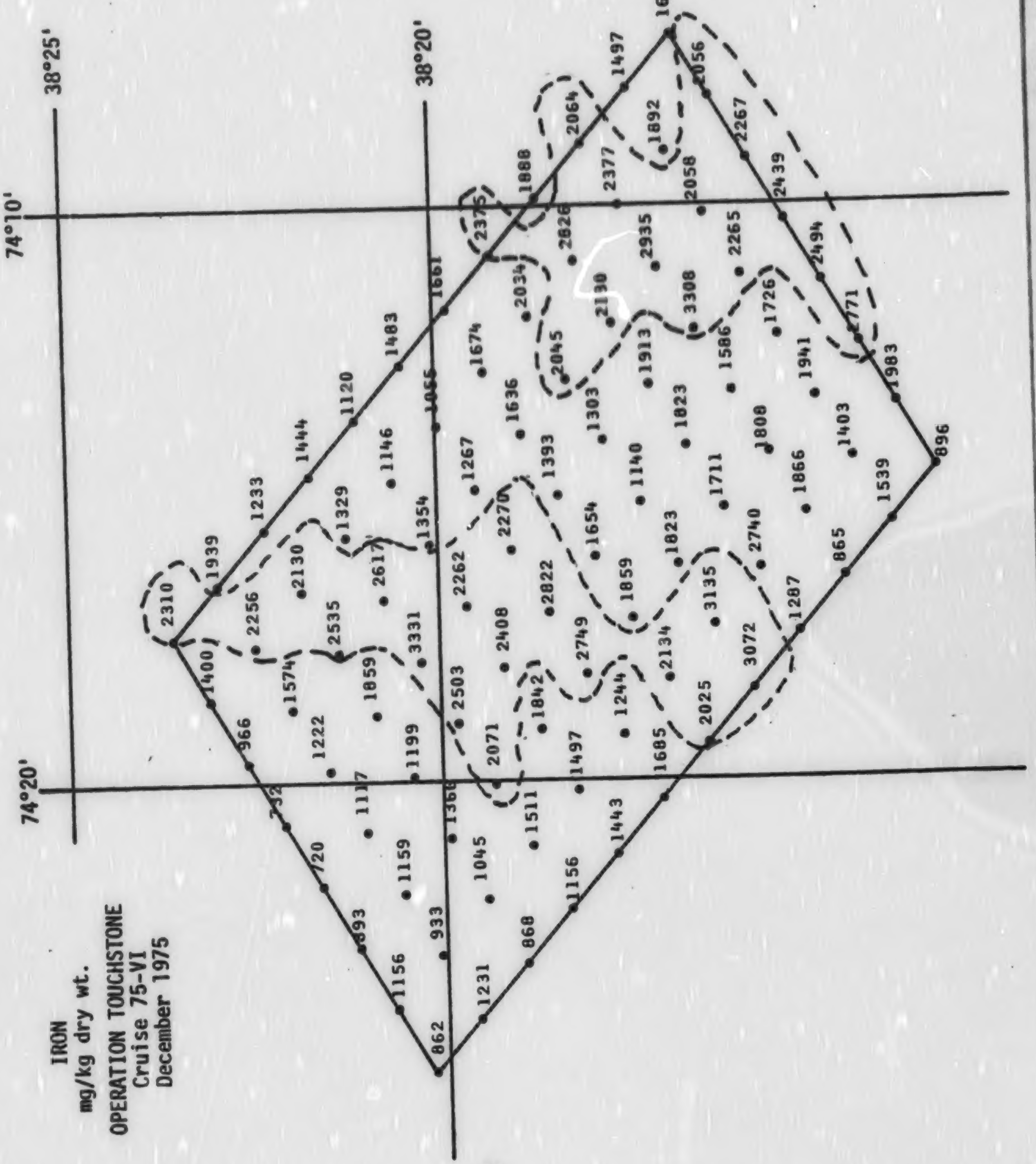
FIGURE 48


38°25'
38°20'
74°10'
74°20'

ZINC
mg/kg dry wt

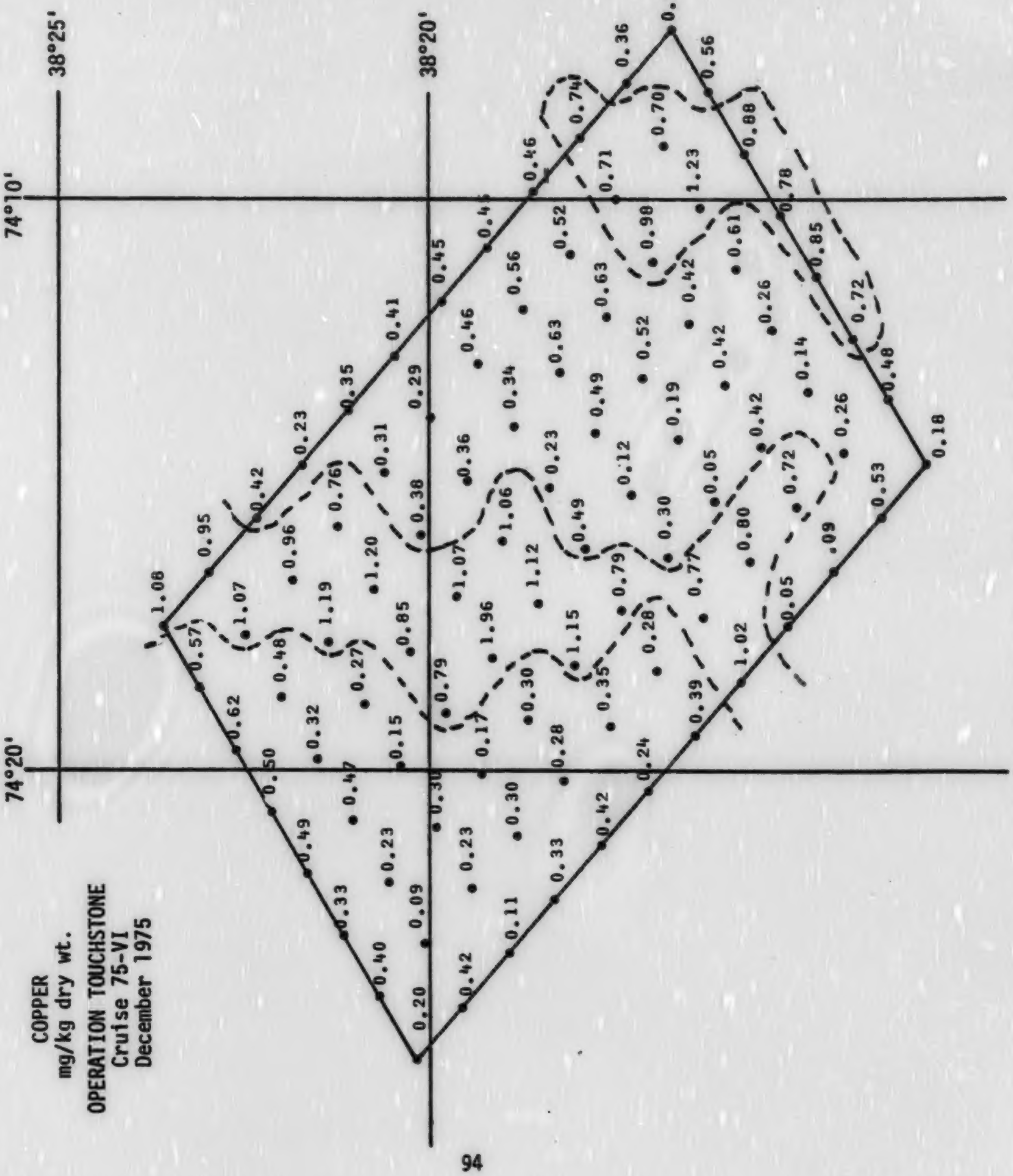
OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

FIGURE 49


38°25'
38°20'
74°10'
74°20'
2310
1939
1233
1444
1120
1483
1661
2375
1888
2064
1497
1669
2056
2267
2439
2494
1771
1983
896
1539
865
1287
3072
2025
1685
1443
1156
868
1231
862
1400
966
732
720
893
1156
2256
2130
1329
1146
1055
1674
2034
2826
2377
1892
2058
2935
2130
2045
1636
1267
1354
2617
2535
1574
1859
3331
2262
2270
1393
1303
1913
3308
2265
1726
1586
1823
1140
1654
2822
2408
2503
1199
1222
1117
1159
1368
933
1045
2071
1842
2749
1859
1823
1711
1808
1941
1403
1866
2740
3135
2134
1244
1497
1511

IRON
mg/kg dry wt.
OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

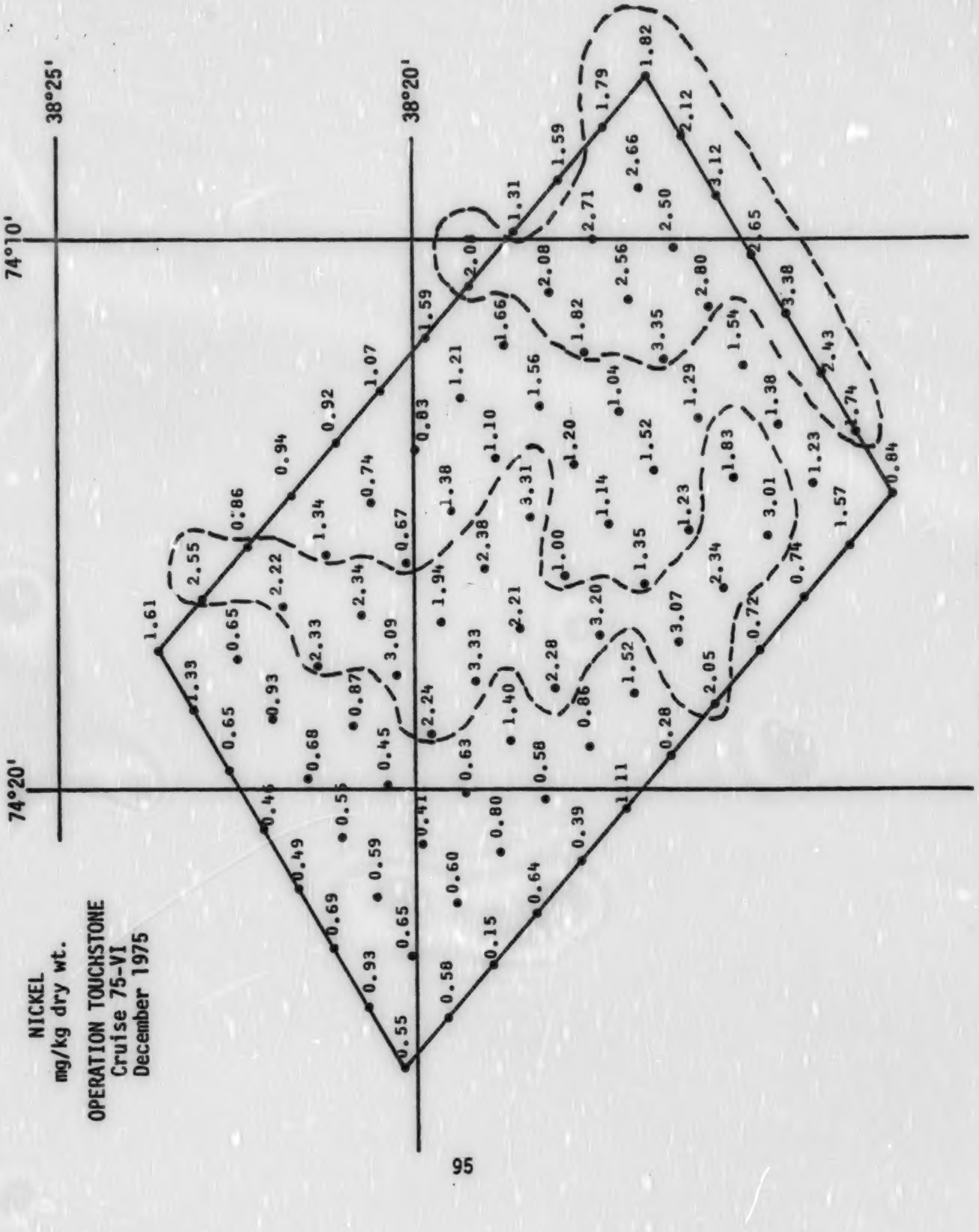
FIGURE 50



38°25'
38°20'
74°10'
74°20'
1.08
0.95
0.42
0.23
0.35
0.41
0.45
0.45
0.46
0.74
0.36
0.21
0.56
0.88
0.78
0.85
0.72
0.48
0.18
0.53
.09
0.05
1.02
0.39
0.24
0.42
0.33
0.11
0.42
0.20
0.40
0.33
0.49
0.50
0.62
0.57
1.07
0.96
0.76
0.31
0.29
0.46
0.56
0.52
0.71
0.70
1.23
0.98
0.61
0.42
0.63
0.63
0.34
0.36
0.38
1.20
1.19
0.48
0.32
0.47
0.23
0.09
0.23
0.30
0.28
0.35
0.28
0.77
0.80
0.72
0.26
0.14
0.26
0.42
0.42
0.19
0.52
0.49
0.12
0.05
0.30
0.79
1.12
1.06
0.23
0.49
1.07
1.96
1.15
0.30
0.17
0.30
0.15
0.85
0.27
0.79

COPPER
mg/kg dry wt.
OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

FIGURE 51

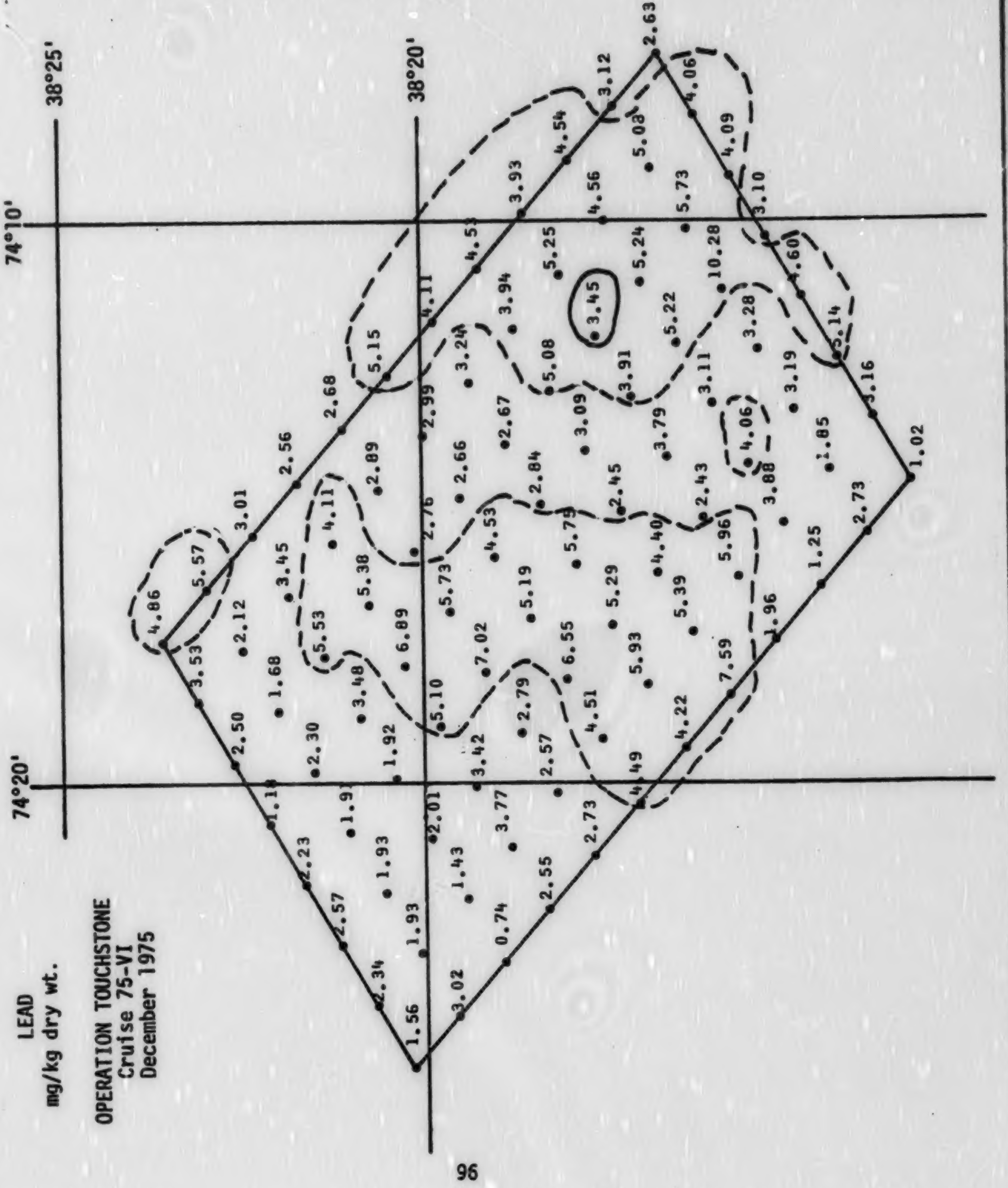


38°25'
38°20'
74°10'
74°20'
1.82
1.79
1.59
1.31
2.12
2.66
3.12
2.71
2.50
2.65
2.08
2.56
2.80
3.38
2.08
1.59
1.66
1.82
3.35
1.54
2.43
1.07
1.21
1.56
1.04
1.29
1.74
0.92
0.83
1.10
1.20
1.52
1.83
1.38
1.23
0.84
0.94
0.74
1.38
3.31
1.14
1.23
3.01
1.57
0.86
1.34
0.67
2.38
1.00
1.35
2.34
0.74
2.55
2.22
2.34
1.94
2.21
3.20
3.07
0.72
1.61
0.65
2.33
3.09
3.33
2.28
1.52
2.05
1.39
0.93
0.87
2.24
1.40
0.86
0.65
0.68
0.45
0.63
0.58
0.28
0.46
0.55
0.41
0.80
0.39
1.11
0.49
0.59
0.60
0.64
0.69
0.65
0.15
0.93
0.58
0.55

NICKEL
mg/kg dry wt.

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

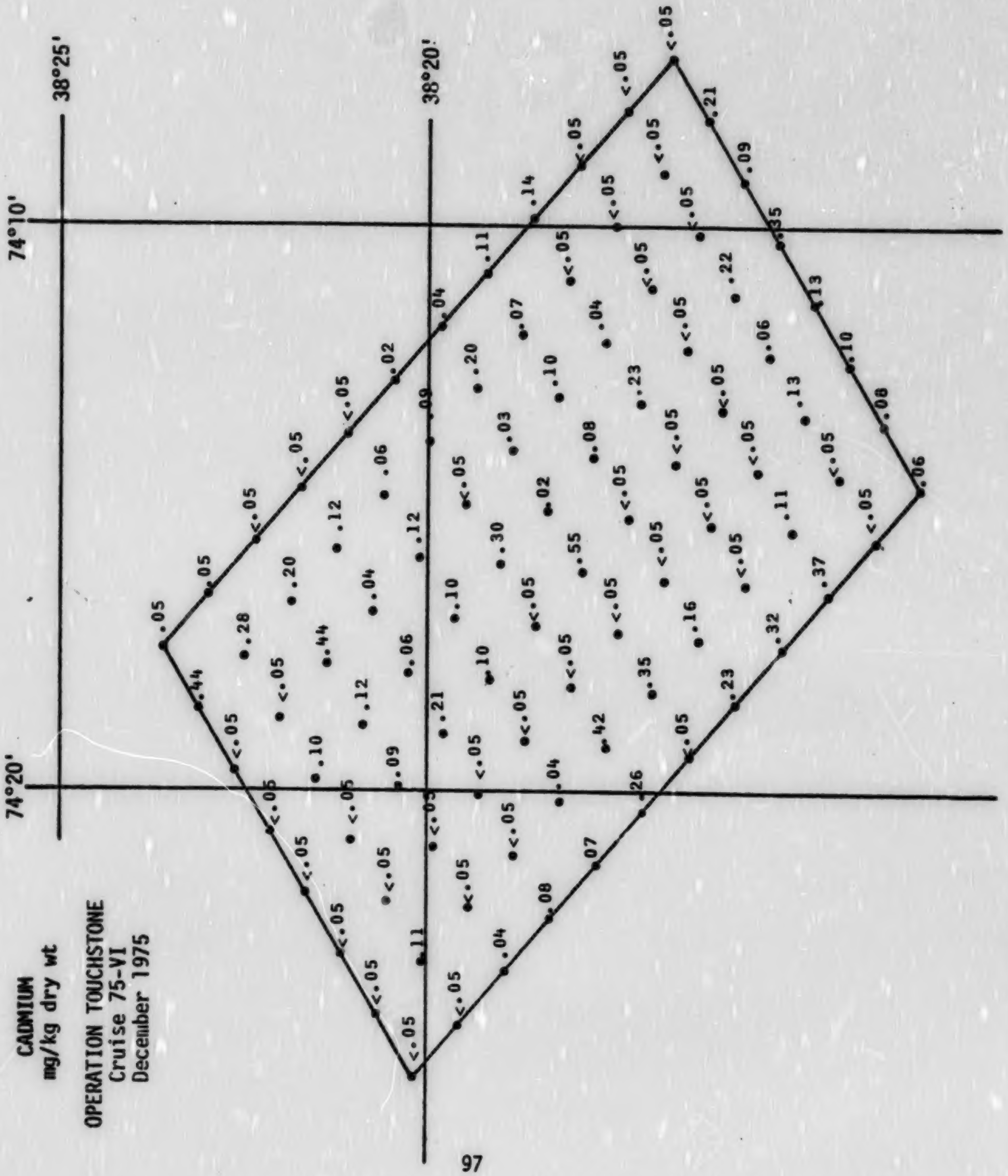
FIGURE 52


38°25'
38°20'
74°10'
74°20'
4.86
5.57
3.01
2.56
2.68
5.15
4.11
4.53
3.93
4.54
3.12
2.63
4.06
4.09
3.10
4.60
5.14
3.16
1.02
2.73
1.25
1.96
7.59
4.22
4.49
2.73
2.55
0.74
3.02
1.56
2.34
2.57
2.23
1.18
2.50
3.53
2.12
3.45
4.11
2.89
2.99
3.24
3.94
5.25
4.56
5.03
5.73
5.24
3.45
5.08
3.91
5.22
10.28
3.28
3.11
3.19
4.06
1.85
3.88
2.43
5.96
3.79
2.45
3.09
2.67
2.84
2.66
2.76
5.38
5.53
1.68
2.30
1.91
1.93
1.93
3.48
1.92
6.89
5.73
5.10
3.42
2.01
1.43
3.77
2.79
7.02
4.53
5.19
5.79
6.55
2.57
4.51
5.29
5.93
4.40
5.39

LEAD
mg/kg dry wt.

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

FIGURE 53



38°25'
38°20'
74°10'
74°20'
.05
.44
<.05
.05
<.05
<.05
.02
.04
.11
.14
.21
.09
.35
.13
.10
.08
.06
.28
.20
.12
.06
.09
.07
.22
.30
.55
.23
.03
.08
.02
.42
.35
.16
.37
.32
.23
.26
.07
.04
.21
.10
.12
.04
.11

CADMIUM
mg/kg dry wt

OPERATION TOUCHSTONE
Cruise 75-VI
December 1975

TABLE 19

METALS IN SEDIMENTS
Operation Hotspot - Cruise 76-II
Duncan's Multiple Range Test
Grid Stations

TOC

Station	Mean
234	373
213	400
223	417
235	467
225	513
208	553
217	563
205	597
220	613
210	647
212	673
207	753
209	797
224	803
219	983
211	1073
214	1120
216	1360
215	1393
226	1550
202	1773
232	2337
203	2577
221	2620
222	2677
201	2836
206	3413
204	3833
218	5463

ANOVA

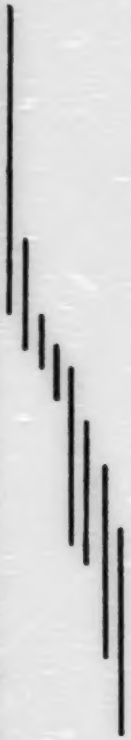
	df	sos	ms	F
Between	28	131445807	4694493	9.11**
Within	58	29855400	514748	
Total	86	161301207		

TABLE 20

METALS IN SEDIMENTS
Operation Hotspot - Cruise 76-II
Duncan's Multiple Range Test
Grid Stations

Nickel

Station	Mean
210	0.25
207	0.25
205	0.30
208	0.30
217	0.30
224	0.33
220	0.40
232	0.40
209	0.45
213	0.47
225	0.50
212	0.67
223	0.90
219	1.13
216	1.17
211	1.33
214	1.33
203	1.37
222	1.37
206	1.57
204	1.60
201	1.67
202	1.67
215	1.70
226	1.77
221	1.80
218	2.43

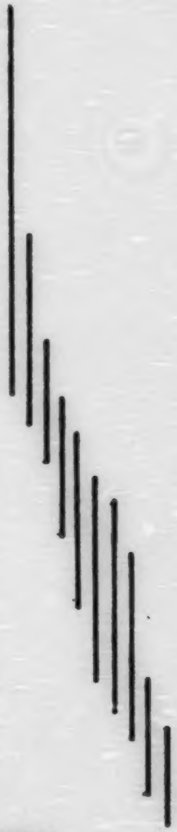


ANOVA

	df	sos	ms	F
Between	26	30.04	1.16	47.82**
Within	50	1.20	0.02	-
Total	76	31.25	-	-

Zinc

Station	Mean
205	2.43
220	2.53
234	2.53
224	2.57
208	2.73
213	2.77
209	2.90
207	3.03
217	3.17
225	3.27
210	3.27
235	3.43
212	4.50
232	4.60
223	5.47
216	6.47
222	7.20
219	7.37
211	7.73
214	7.87
215	8.40
206	8.87
226	9.03
204	9.23
203	9.87
221	10.50
202	11.50
218	11.60
201	12.83



ANOVA

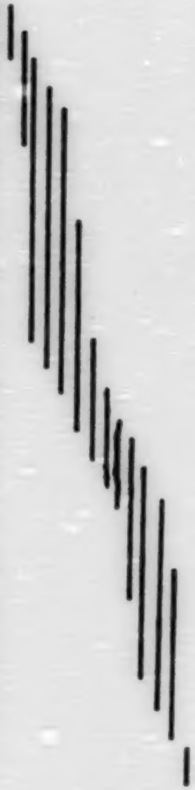
	df	sos	ms	F
Between	27	887.45	32.87	20.77**
Within	59	93.35	1.58	-
Total	86	980.81	-	-

TABLE 21

METALS IN SEDIMENTS
Operation Hotspot - Cruise 76-II
Duncan's Multiple Range Test
Grid Stations

Chromium

Station	Mean
209	1.60
220	1.80
213	2.20
234	2.30
207	2.33
210	2.40
217	2.47
205	2.47
224	2.57
235	2.60
208	2.67
232	2.77
225	2.87
212	2.90
223	3.07
204	3.43
216	3.57
219	3.87
211	3.97
222	4.00
214	4.03
206	4.20
221	4.23
215	4.43
226	4.53
202	4.73
203	5.27
201	5.57
218	6.07

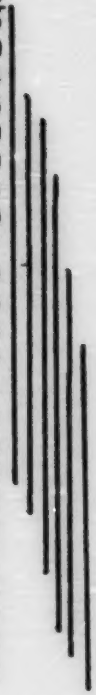


ANOVA

	df	sos	ms	F
Between	28	115.44	4.12	43.58**
Within	58	5.49	0.09	-
Total	86	120.93	-	-

Lead

Station	Mean
220	0.45
217	0.80
235	0.94
232	0.95
224	1.00
205	1.20
207	1.43
222	1.60
221	1.67
212	1.70
214	1.80
219	1.80
215	1.90
211	1.93
223	2.00
218	2.30
216	2.70
202	3.23
203	3.33
225	3.37
204	3.60
226	3.70
206	4.03
201	4.13



ANOVA

	df	sos	ms	F
Between	23	76.21	3.31	2.48**
Within	42	56.03	1.33	-
Total	65	132.24	-	-

FIGURE 54

ORGANIC CARBON SEARCH GRID

LORAN C LOCATIONS and

STATION NUMBERS

OPERATION HOTSPOT
Cruise 76-II
August 1976

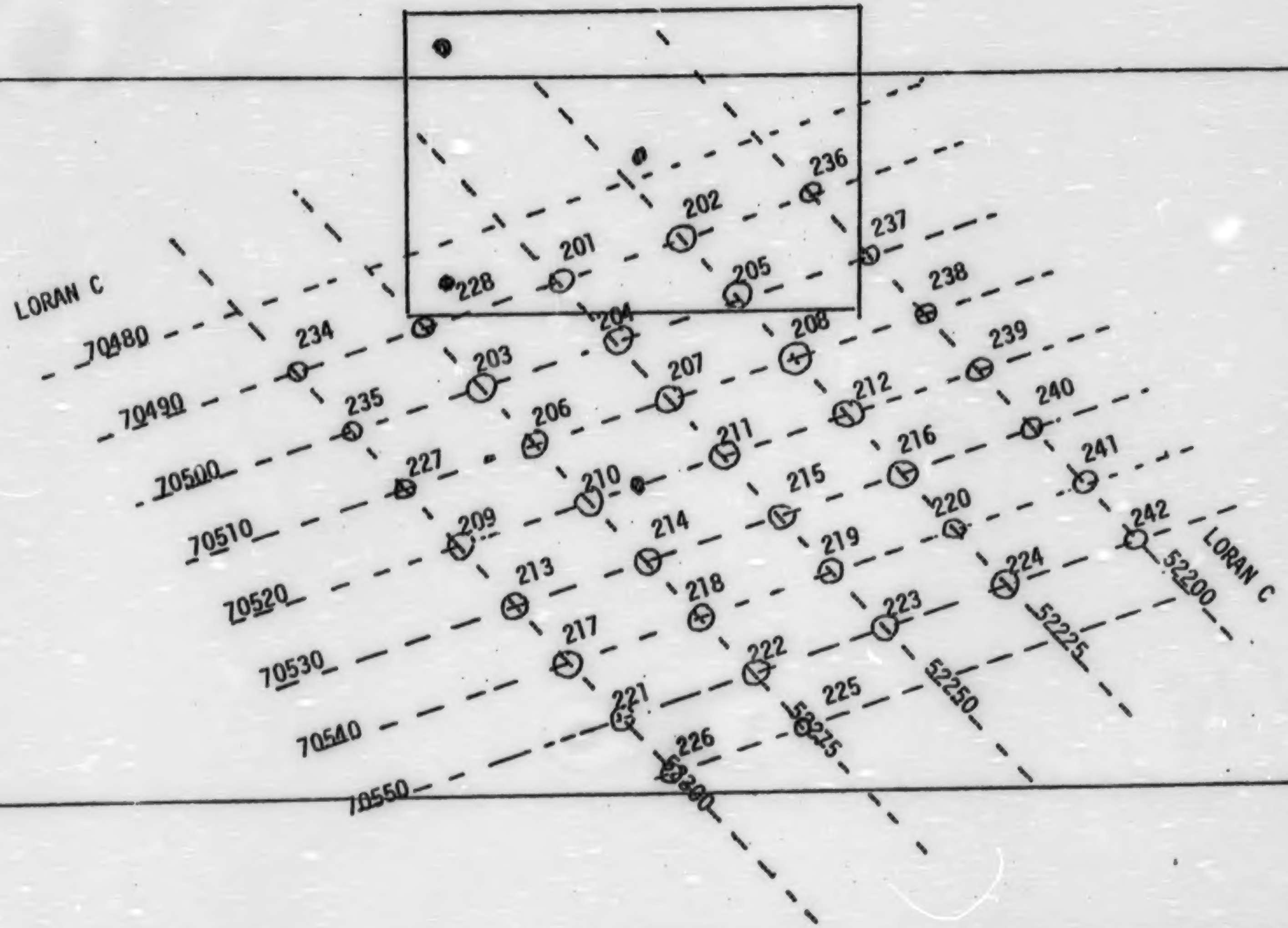
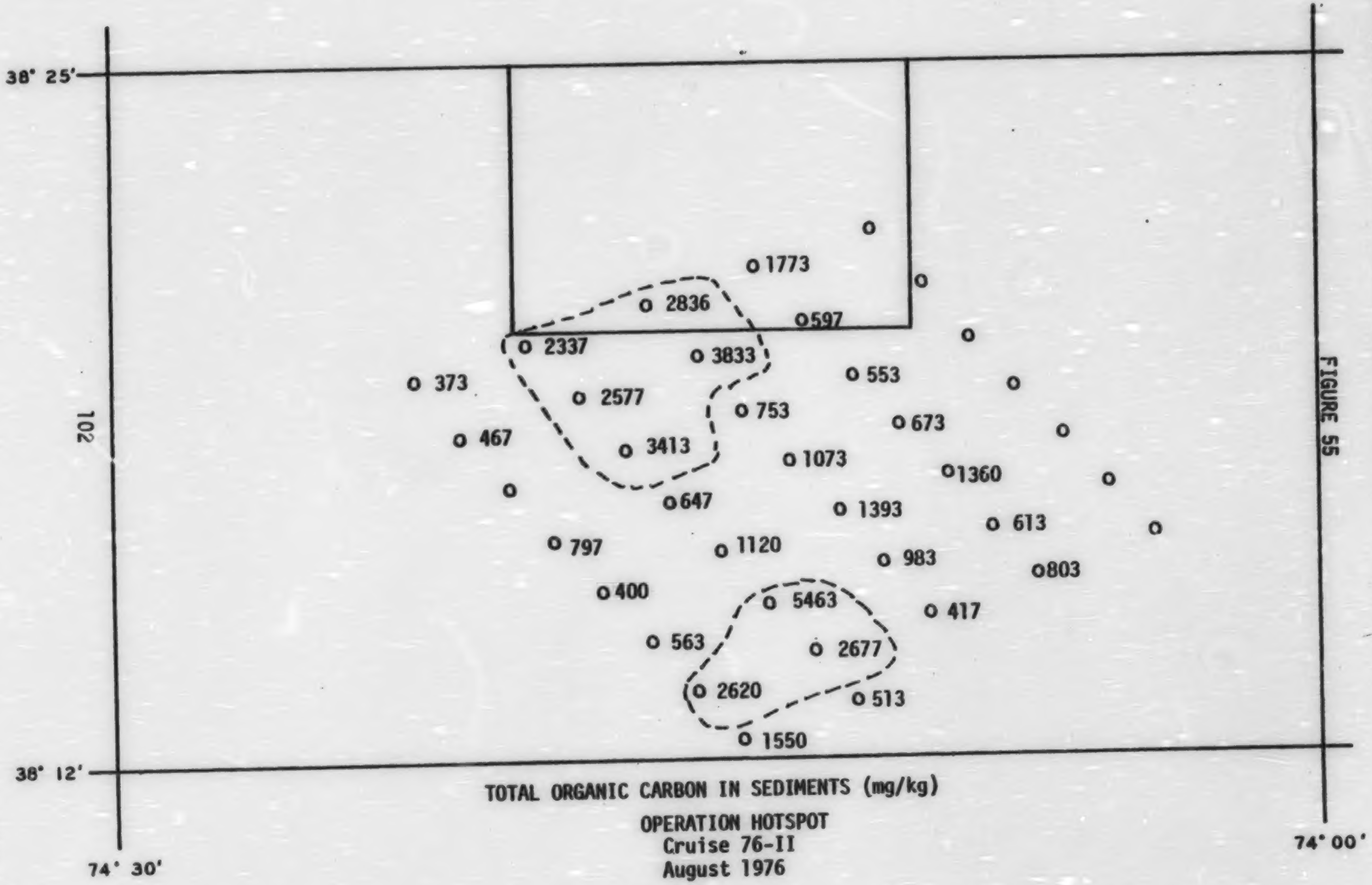

LORAN C
70480
70490
70500
70510
70520
70530
70540
70550
LORAN C
52200
52225
52250
52275
52300
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
234
235
236
237
238
239
240
241
242

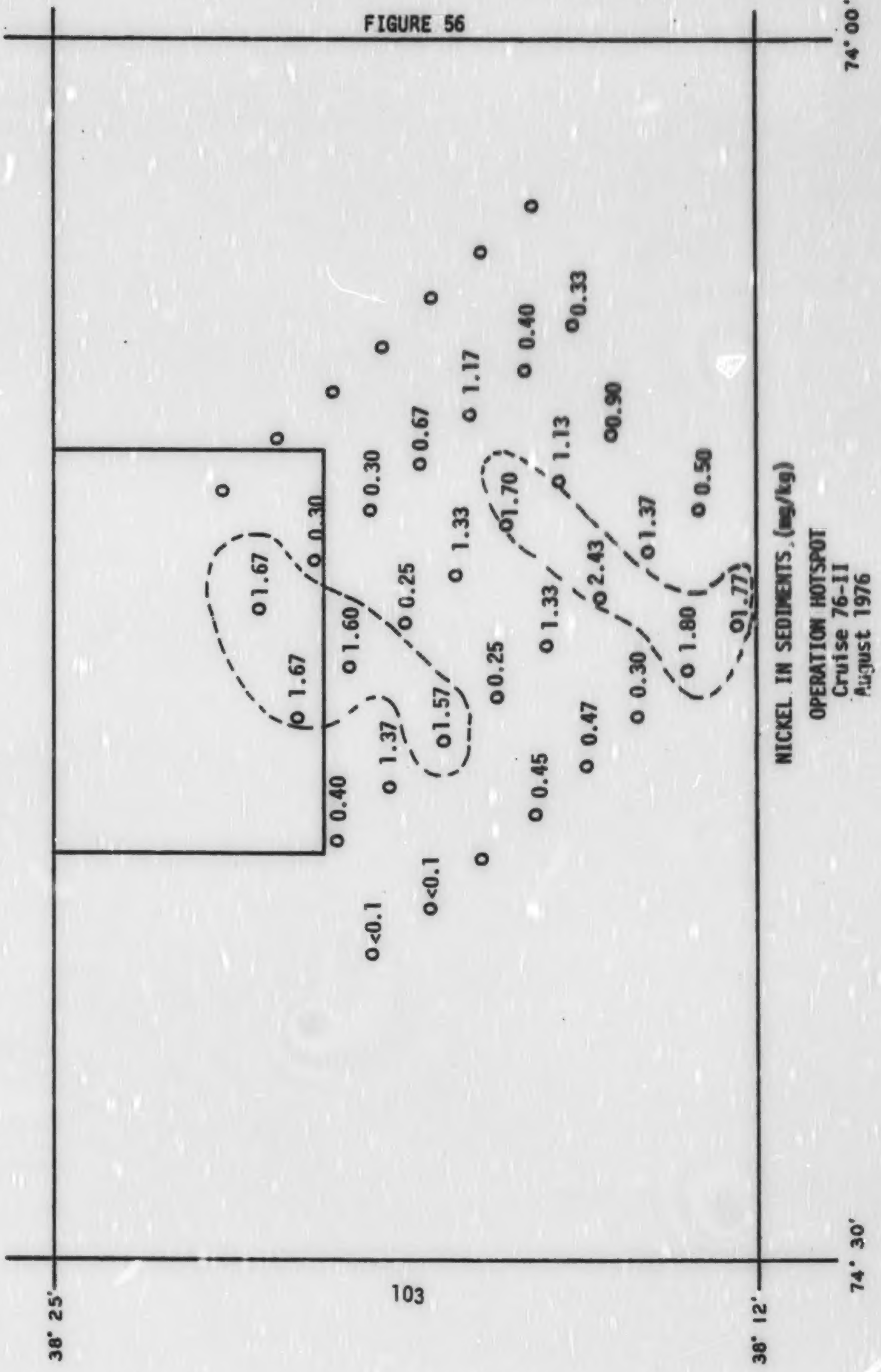
FIGURE 55


38° 25'
38° 12'
74° 30'
74° 00'
1773
2836
597
2337
3833
373
553
2577
753
673
467
3413
1073
1360
647
1393
613
797
1120
983
803
400
5463
417
563
2677
2620
513
1550

TOTAL ORGANIC CARBON IN SEDIMENTS (mg/kg)

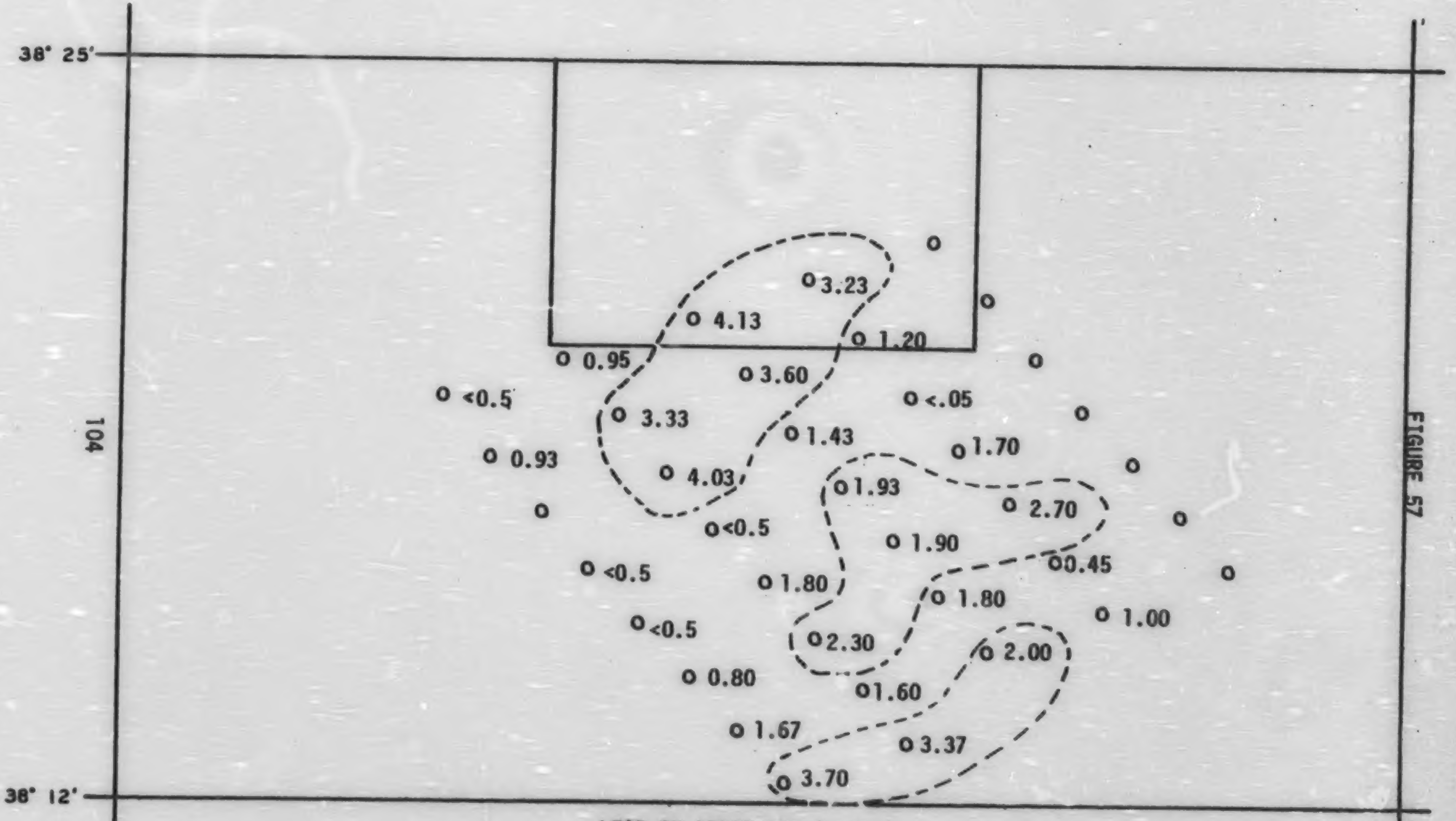
OPERATION HOTSPOT
Cruise 76-II
August 1976

FIGURE 56


74° 00'
74° 30'
38° 25'
38° 12'
0.30
0.40
1.67
1.67
1.60
0.30
0.25
1.37
1.57
0.67
1.33
0.25
1.17
<0.1
<0.1
0.40
1.70
1.13
1.33
0.45
0.33
0.90
2.43
0.47
1.37
0.30
0.50
1.80
1.77

NICKEL IN SEDIMENTS (mg/kg)
OPERATION HOTSPOT
Cruise 76-II
August 1976

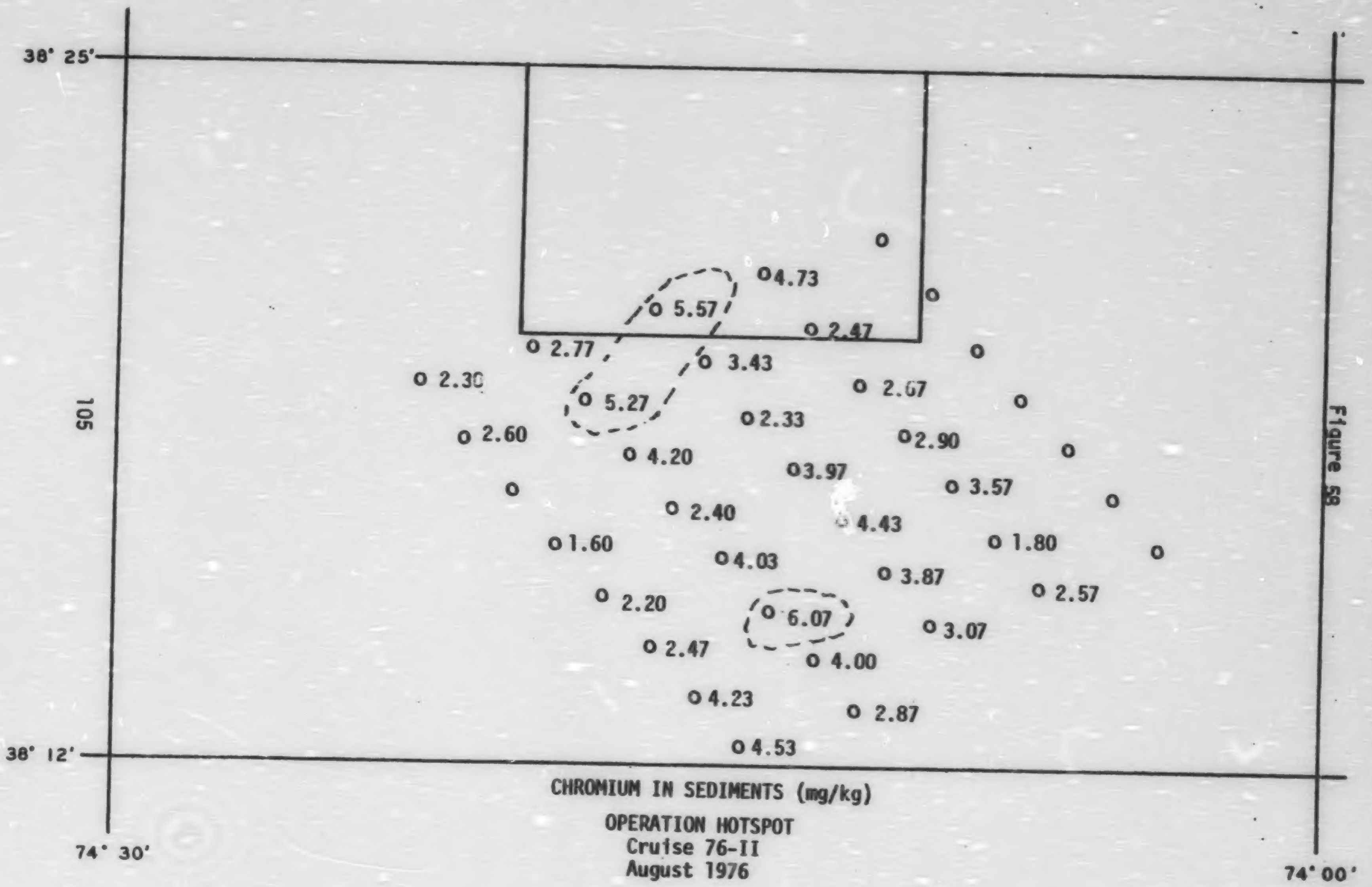
FIGURE 57


38° 25'
38° 12'
74° 30'
74° 00'
3.23
4.13
1.20
0.95
3.60
<0.5
<.05
3.33
1.43
1.70
0.93
4.03
1.93
2.70
<0.5
1.90
<0.5
0.45
1.80
1.80
1.00
<0.5
2.30
2.00
0.80
1.60
1.67
3.37
3.70

LEAD IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

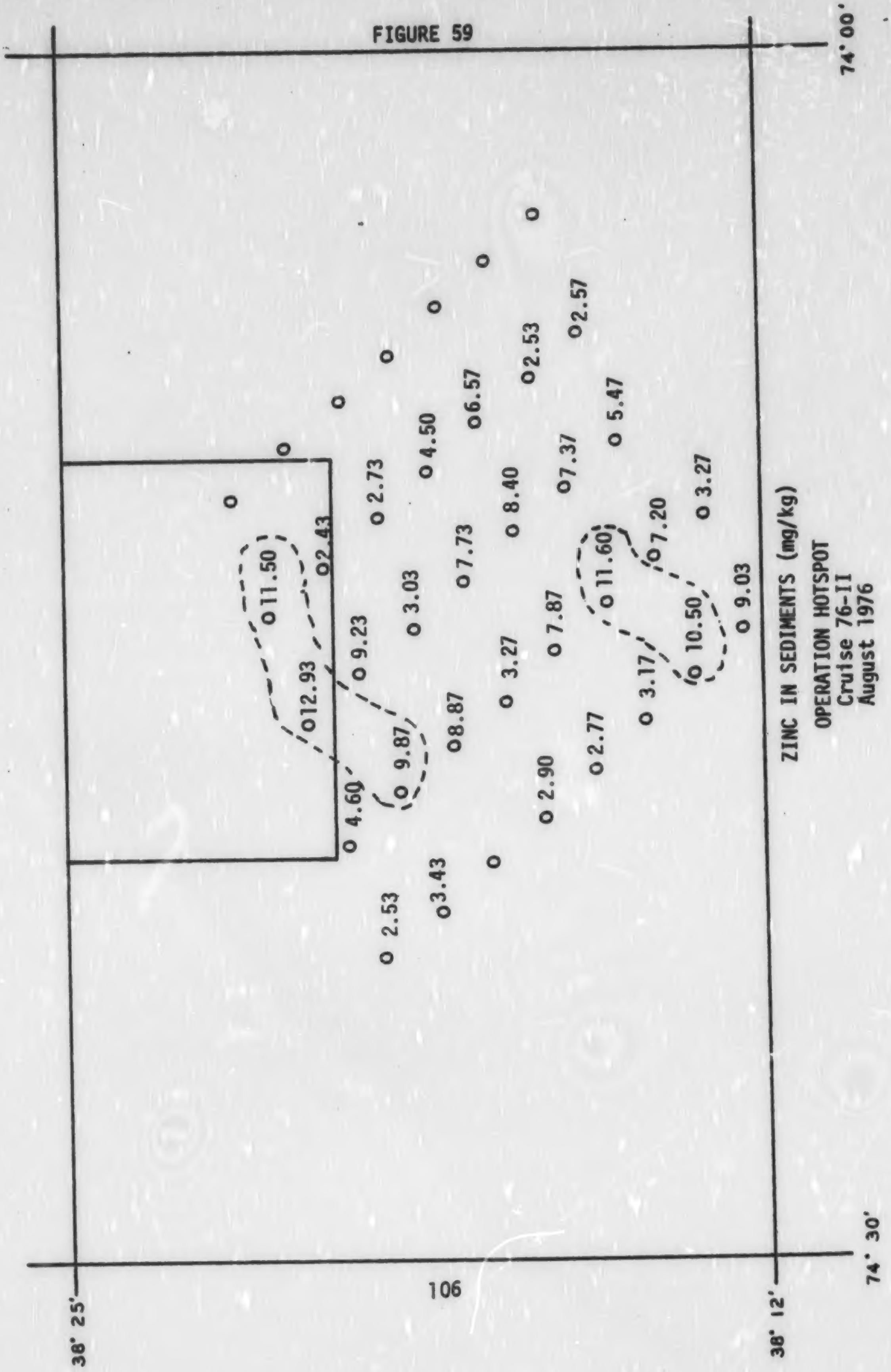
Figure 58


38° 25'
38° 12'
74° 30'
74° 00'
4.73
5.57
2.47
2.77
3.43
2.30
5.27
2.67
2.33
2.60
2.90
4.20
3.97
3.57
2.40
4.43
1.60
1.80
4.03
3.87
2.20
2.57
6.07
3.07
2.47
4.00
4.23
2.87
4.53

CHROMIUM IN SEDIMENTS (mg/kg)

OPERATION HOTSPOT
Cruise 76-II
August 1976

FIGURE 59


74° 00'
74° 30'
38° 25'
38° 12'
11.50
2.43
12.93
9.23
9.87
4.60
2.73
3.03
8.87
4.50
7.73
3.27
2.90
2.53
3.43
6.57
8.40
7.87
2.77
2.53
7.37
11.60
3.17
2.57
5.47
7.20
10.50
3.27
9.03

ZINC IN SEDIMENTS (mg/kg)
OPERATION HOTSPOT
Cruise 76-II
August 1976

TABLE 22
METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
Grid Stations

Copper

Station	Mean
237	0.20
236	0.23
234	0.27
205	0.30
209	0.33
235	0.37
220	0.40
227	0.40
238	0.40
202	0.47
224	0.47
225	0.47
208	0.53
212	0.60
216	0.63
223	0.63
213	0.67
228	0.67
207	0.70
241	0.73
204	0.83
219	0.83
242	0.90
239	0.97
217	0.97
210	0.97
211	1.00
222	1.00
215	1.30
206	1.33
240	1.43
226	1.63
214	1.90
218	2.20
221	2.57
203	2.63
201	3.27

TOC

Station	Mean
209	275
212	287
205	316
234	333
213	383
236	433
207	470
237	493
242	600
224	613
216	665
202	686
227	693
228	747
235	783
225	787
220	793
208	827
223	873
219	913
211	933
210	963
204	980
241	1010
217	1077
238	1103
215	1227
240	1400
206	1623
239	1687
214	1700
222	2007
201	2376
218	2433
226	3060
203	3150
201	4250

ANOVA

	df	sos	ms	F
Between	35	55.59	1.59	13.73**
Within	76	8.79	0.13	
Total	111	64.38		

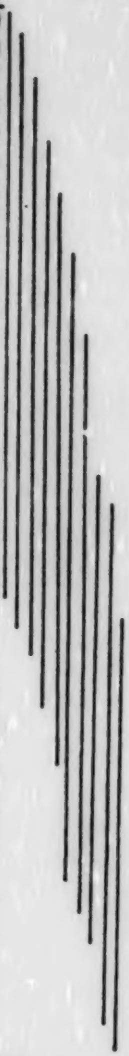
ANOVA

	df	sos	ms	F
Between	36	86211348	2394760	16.1**
Within	72	10706433	148700	
Total	108	96917781		

TABLE 23
METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
Grid Stations

Nickel

Station	Mean
234	0.40
236	0.50
209	0.57
205	0.63
237	0.70
235	0.80
228	0.83
238	0.87
208	1.03
213	1.10
227	1.10
207	1.13
202	1.17
220	1.17
225	1.17
223	1.23
212	1.33
204	1.37
216	1.60
240	1.90
219	1.93
224	1.97
222	2.17
217	2.37
210	2.37
239	2.40
211	2.40
241	2.60
242	2.60
206	2.60
214	2.63
203	2.73
215	2.90
226	3.00
201	3.07
218	3.13
221	3.53

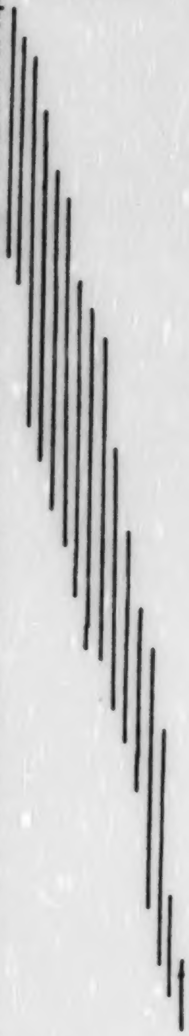


ANOVA

	df	sos	ms	F
Between	36	81.19	2.25	36.17**
Within	74	4.61	0.62	
Total	110	85.80		

Chromium

Station	Mean
220	1.33
236	1.43
238	1.73
228	1.73
202	1.80
234	1.80
237	1.87
209	1.90
204	1.93
213	1.97
205	2.07
225	2.17
216	2.27
235	2.33
224	2.33
207	2.37
240	2.47
223	2.47
208	2.50
219	2.60
212	2.67
227	2.70
239	2.87
241	3.00
222	3.00
217	3.13
210	3.30
242	3.33
211	3.50
203	3.53
226	3.53
215	3.57
214	3.83
206	3.97
218	4.23
221	4.53
201	5.33



ANOVA

	df	sos	ms	F
Between	35	91.33	2.61	27.85**
Within	75	7.03	0.094	
Total	110	98.35		

TABLE 24
METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
Grid Stations

Zinc

Station	Mean
236	1.73
234	2.53
237	2.63
238	2.73
235	3.07
202	3.63
228	3.63
209	3.83
205	3.90
223	3.93
220	4.06
225	4.10
227	4.30
213	4.30
212	4.67
208	4,67
204	5.47
207	6.17
216	6.83
240	7.23
224	7.57
219	7.87
241	8.27
217	8.30
239	8.40
210	8.63
242	8.93
211	8.97
222	8.97
226	9.67
215	10.53
206	11.07
214	11.63
218	12.73
203	13.43
221	14.67
201	15.20

ANOVA

	df	sos	ms	F
Between	36	1428.26	39.67	54.81**
Within	74	53.56	0.72	
Total	110	1481.81		

Lead

Station	Mean
238	0.40
235	1.03
236	1.10
202	1.20
234	1.25
237	1.25
209	1.30
208	1.43
225	1.77
220	1.90
207	1.93
204	2.00
212	2.20
227	2.20
205	2.23
228	2.30
240	2.30
216	2.37
239	2.40
223	2.60
211	2.97
210	3.13
241	3.13
215	3.27
222	3.33
226	3.37
219	3.37
217	3.50
224	3.57
242	3.73
206	4.20
201	5.03
214	5.23
218	5.60
221	6.20
203	6.73

ANOVA

	df	sos	ms	F
Between	36	201.28	5.59	7.74**
Within	74	53.47	0.72	
Total	110	254.74		

INTENSIVE GRID

LORAN C LOCATIONS and

STATION NUMBERS

OPERATION MOGUL
Cruise 77-I
February 1977

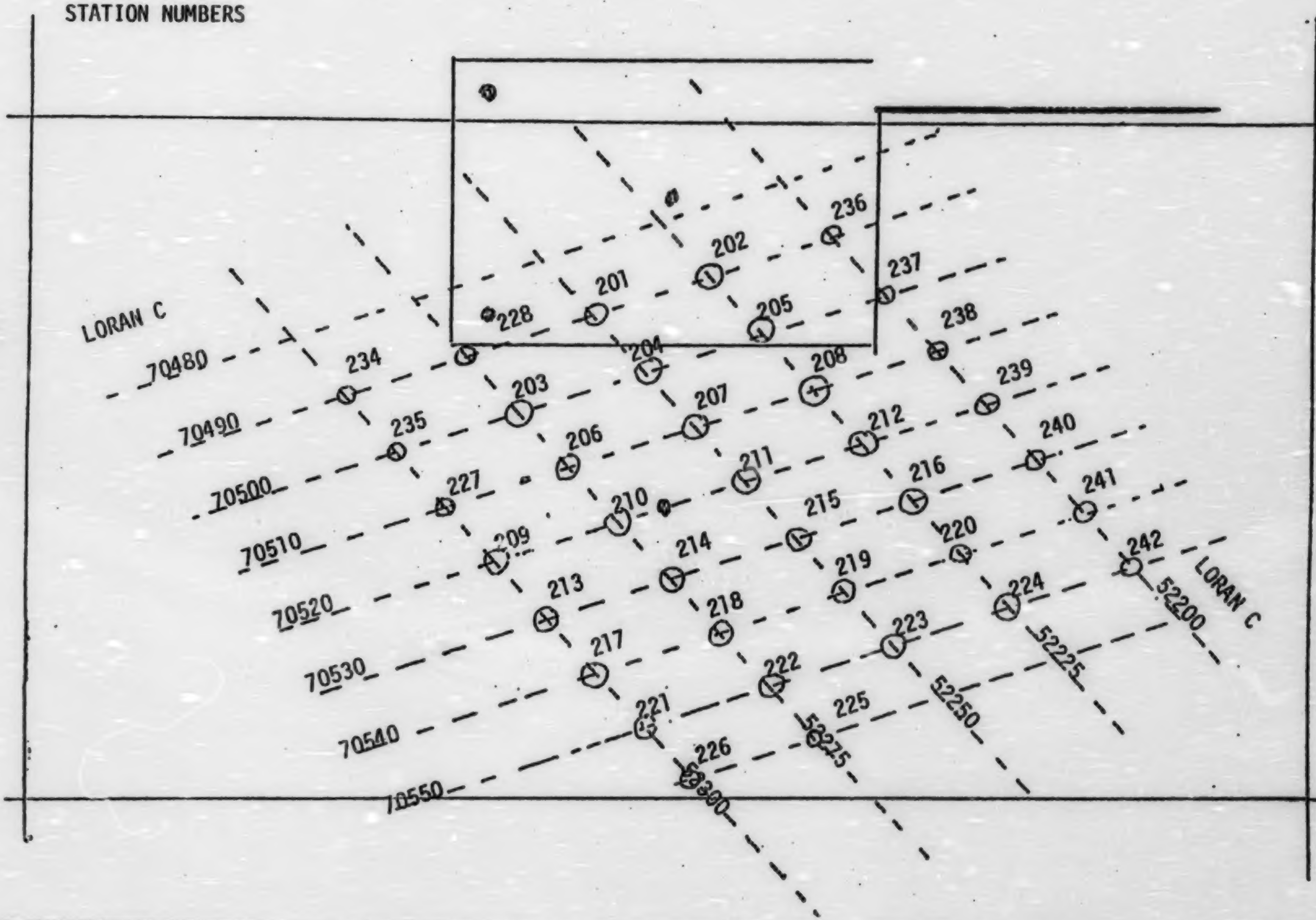
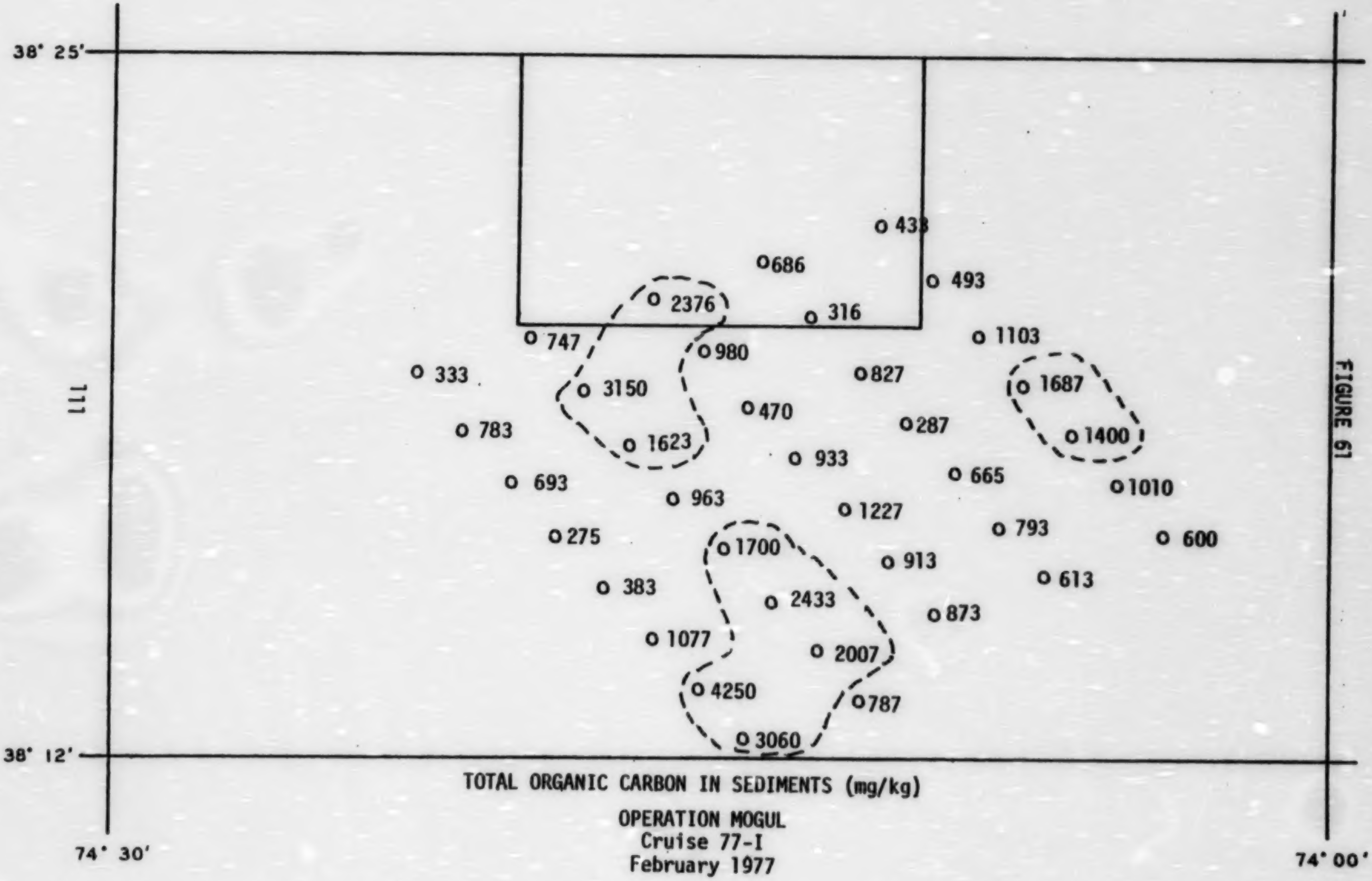

LORAN C
70480
70490
70500
70510
70520
70530
70540
70550
LORAN C
52200
52225
52250
52275
52300
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
234
235
236
237
238
239
240
241
242

FIGURE 60

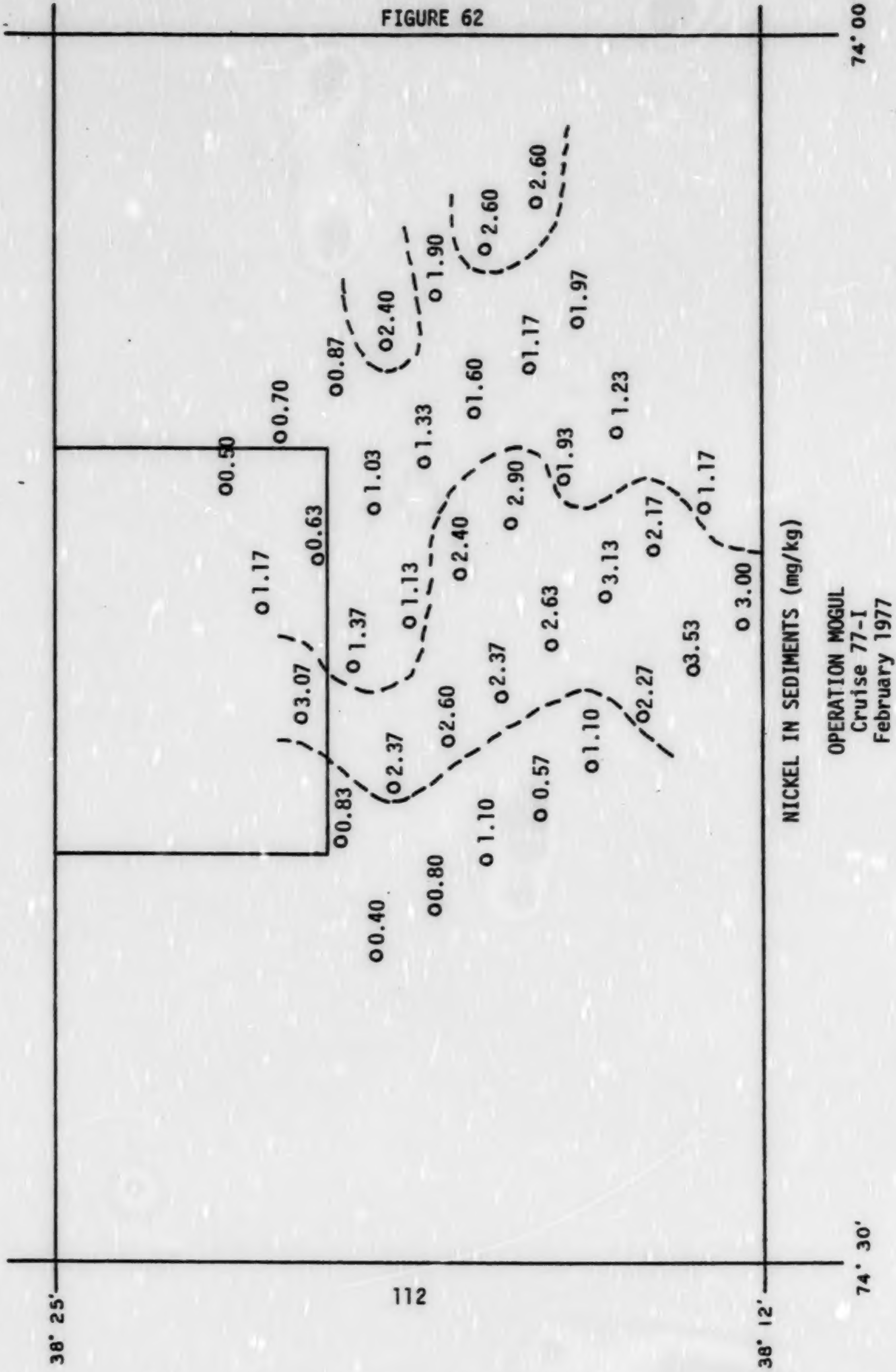
FIGURE 61


38° 25'
38° 12'
74° 30'
74° 00'
433
686
493
2376
316
1103
747
980
827
1687
333
3150
470
287
1400
783
1623
933
665
1010
693
963
1227
793
600
275
1700
913
613
383
2433
873
1077
2007
4250
787
3060

TOTAL ORGANIC CARBON IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

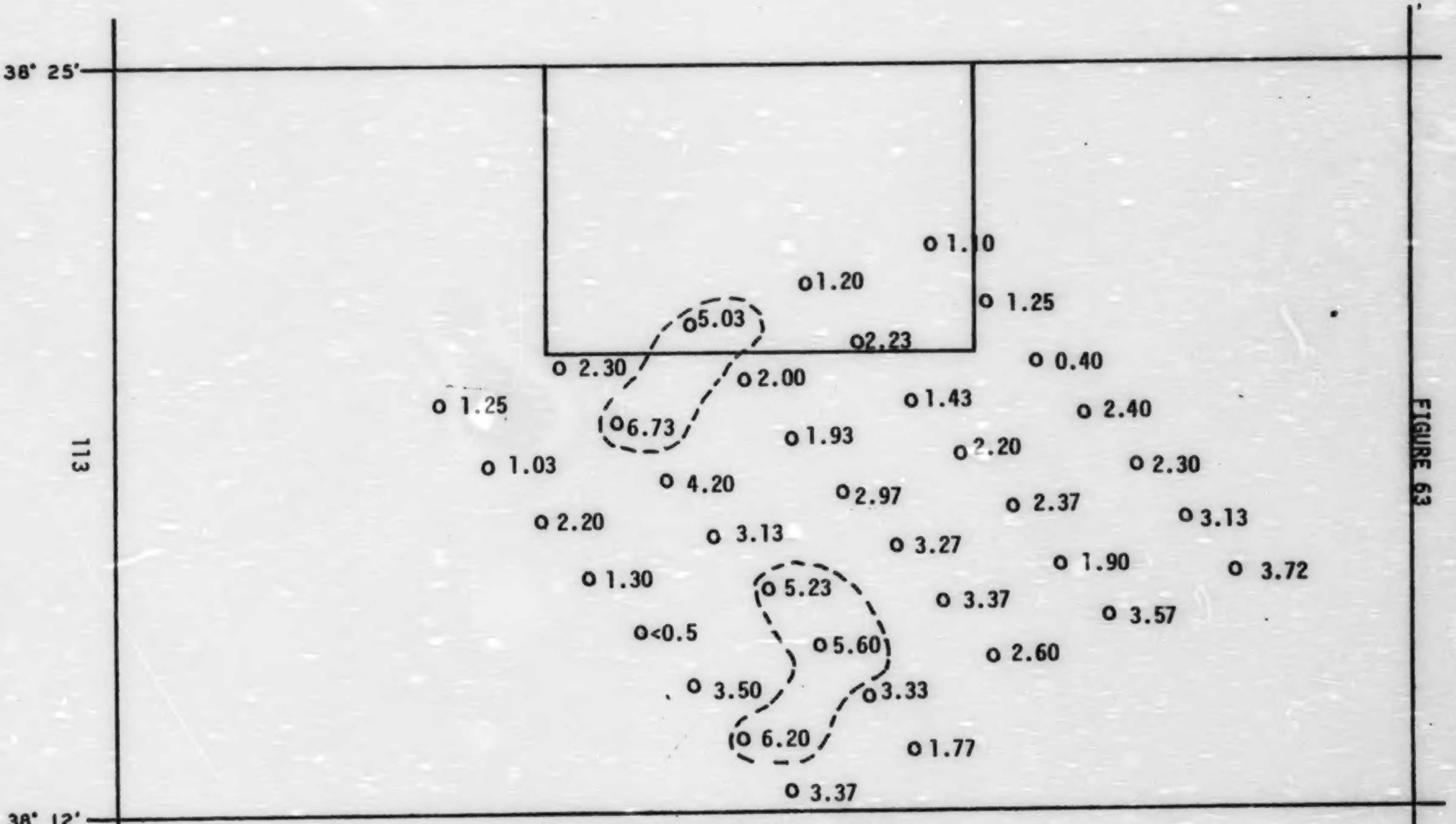
FIGURE 62


74° 00'
74° 30'
38° 25'
38° 12'
0.50
0.70
0.87
2.40
1.90
2.60
2.60
1.97
1.17
1.60
1.33
1.03
0.63
1.17
1.37
1.13
2.40
2.90
1.93
1.23
1.17
2.17
3.13
2.63
2.37
3.07
3.00
3.53
2.27
1.10
2.60
2.37
0.83
0.57
1.10
0.80
0.40

NICKEL IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

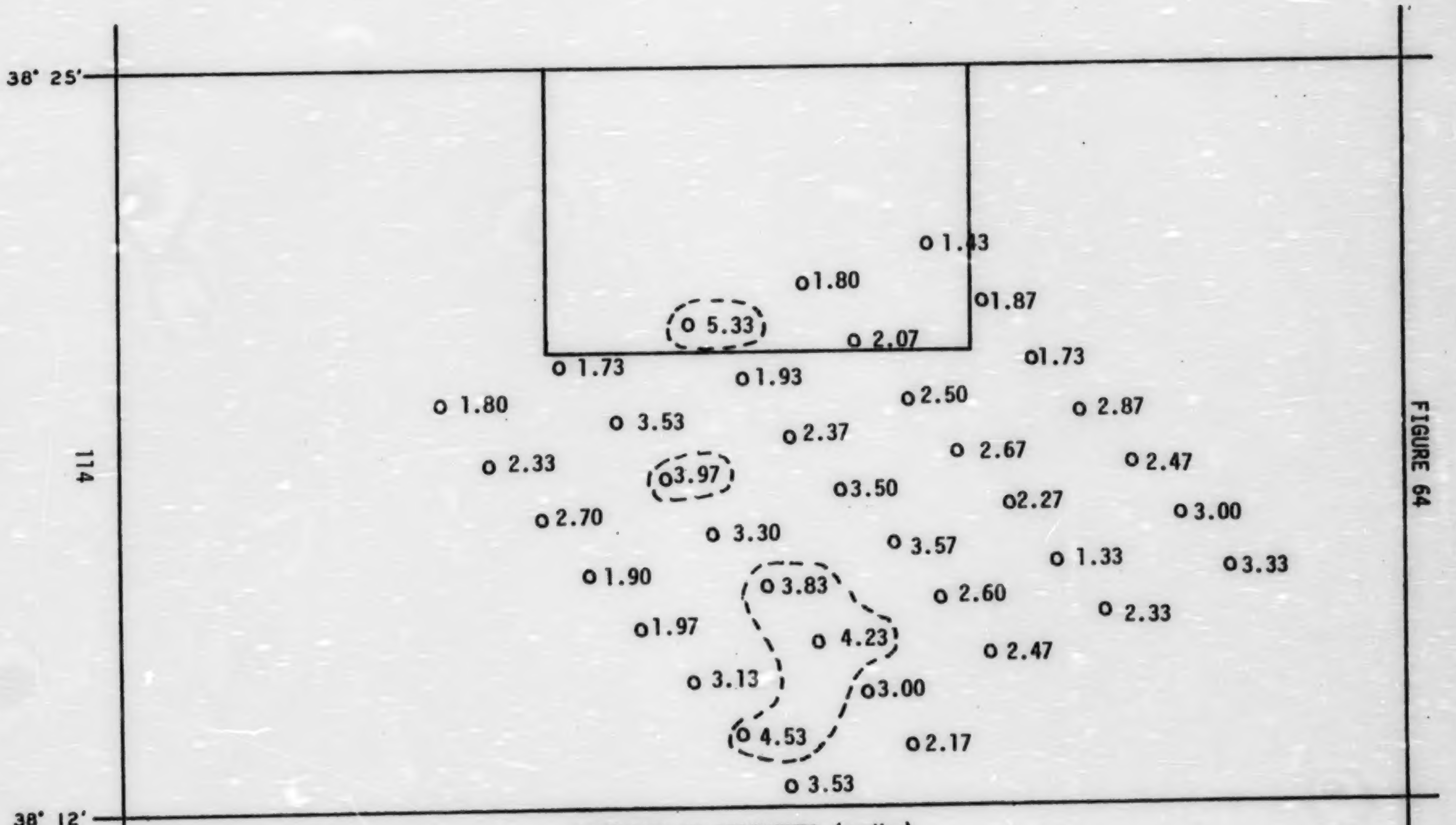
FIGURE 63


38° 25'
38° 12'
74° 30'
74° 00'
1.10
1.20
1.25
5.03
2.23
2.30
2.00
0.40
1.25
1.43
2.40
6.73
1.93
2.20
2.30
1.03
4.20
2.97
2.37
3.13
2.20
3.13
3.27
1.90
3.72
1.30
5.23
3.37
3.57
<0.5
5.60
2.60
3.50
3.33
6.20
1.77
3.37

LEAD IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

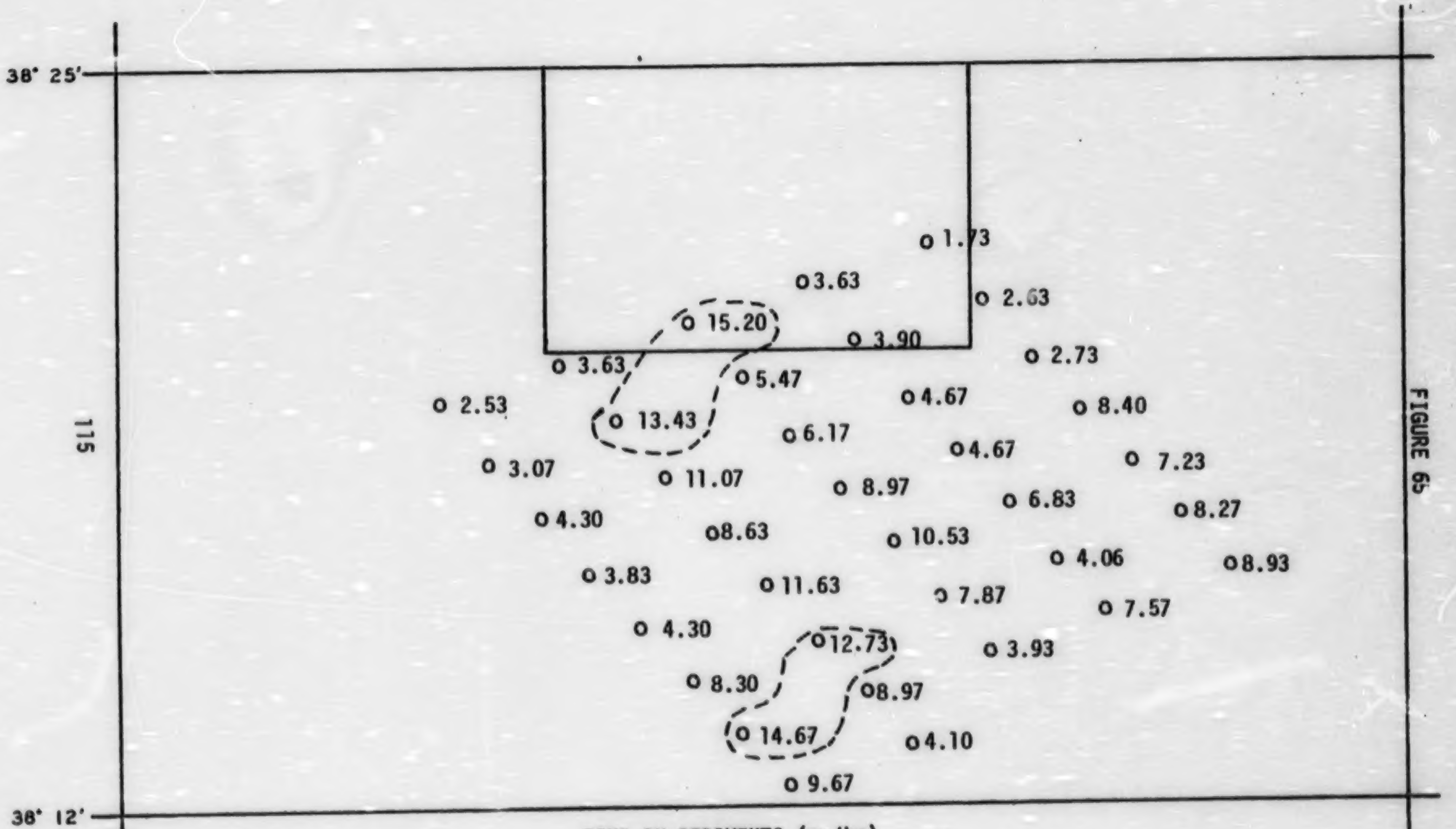
FIGURE 64


38° 25'
38° 12'
74° 30'
74° 00'
1.43
1.80
1.87
5.33
2.07
1.73
1.73
1.93
1.80
2.50
2.87
3.53
2.37
2.67
2.33
3.97
2.47
3.50
2.27
2.70
3.00
3.30
3.57
1.33
3.33
1.90
3.83
2.60
2.33
1.97
4.23
2.47
3.13
3.00
4.53
2.17
3.53

CHROMIUM IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

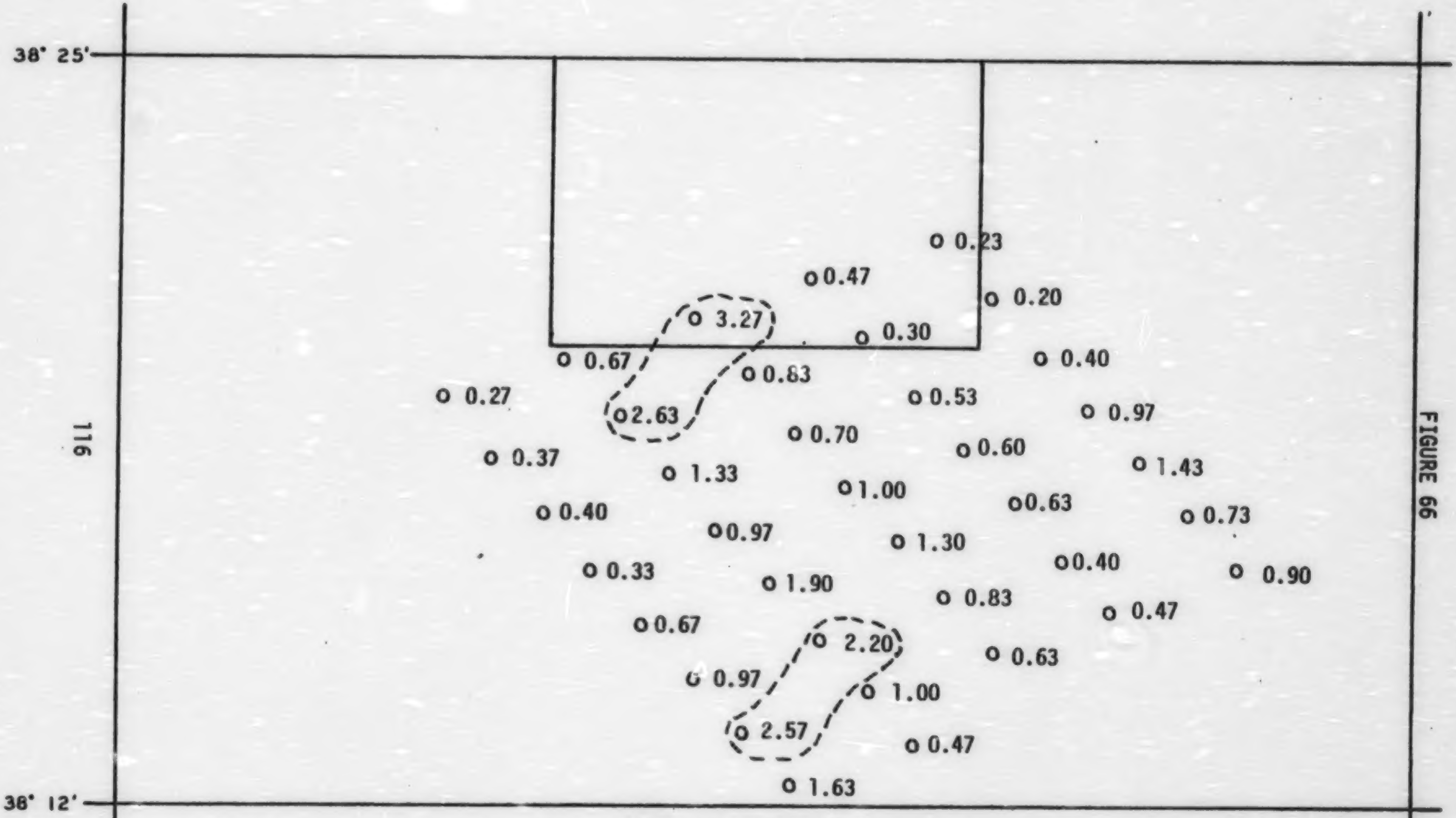
FIGURE 65


38° 25'
38° 12'
74° 30'
74° 00'
1.73
3.63
2.63
15.20
3.90
2.73
3.63
5.47
4.67
8.40
2.53
13.43
6.17
4.67
7.23
3.07
11.07
8.97
6.83
8.27
4.30
8.63
10.53
4.06
8.93
3.83
11.63
7.87
7.57
4.30
12.73
3.93
8.30
8.97
14.67
4.10
9.67

ZINC IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

FIGURE 66


38° 25'
38° 12'
74° 30'
74° 00'
0.23
0.47
0.20
3.27
0.30
0.67
0.40
0.83
0.27
0.53
0.97
2.63
0.70
0.60
0.37
1.33
1.43
1.00
0.63
0.40
0.73
0.97
1.30
0.33
0.40
0.90
1.90
0.83
0.67
0.47
2.20
0.63
0.97
1.00
2.57
0.47
1.63

COPPER IN SEDIMENTS (mg/kg)

OPERATION MOGUL
Cruise 77-I
February 1977

COMPARISONS OF INTENSIVE GRID WITH REGIONAL GRID

The data from the regional monitoring stations were pooled with the data from the intensive grid from the February 1977 cruise, Operation Mogul, and subjected to the new Duncan multiple range test. The results are shown in Tables 25 through 30.

Total organic carbon was significantly higher in concentration in the impacted areas of the intensive grid than on the surrounding shelf regions. Station 20, in the acid waste site, had concentrations at levels found in the intensive grid. The metal parameters, chromium, nickel, copper, lead, and zinc showed a similarity with organic carbon of stations with significantly elevated concentrations.

TABLE 25
METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

TOC

Station	Mean	Station	Mean
G-34	77	235	783
D	156	225	787
33	176	220	793
9	250	F	820
209	275	208	827
212	287	24	850
A	290	223	873
205	316	219	913
234	333	211	933
213	383	210	963
2	386	204	980
23	386	241	1010
17	393	22	1036
32	413	217	1077
236	433	238	1103
E	453	G-19	1176
207	470	215	1227
B	486	240	1400
8	493	206	1623
237	493	20	1680
14	593	239	1687
242	600	214	1700
224	613	222	2007
216	665	201	2376
202	686	218	2433
227	693	226	3060
C	713	203	3150
228	747	201	4250

ANOVA

	df	sos	ms	F
Between	55	10618056.0	193055.5	16.87**
Within	110	1258623.3	11442.0	
Total	165	11876679.3		

TABLE 26

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

Chromium

Station	Mean	Station	Mean
260	1.33	G-19	2.63
236	1.43	212	2.67
238	1.73	227	2.70
228	1.73	14	2.73
E	1.77	33	2.73
17	1.77	239	2.87
202	1.80	F	2.97
234	1.80	241	3.00
237	1.87	222	3.00
209	1.90	217	3.13
204	1.93	210	3.30
213	1.97	242	3.33
2	2.02	32	3.37
205	2.07	C	3.47
8	2.13	211	3.50
225	2.17	203	3.53
D	2.17	226	3.53
A	2.23	215	3.57
216	2.27	9	3.73
235	2.33	B	3.80
224	2.33	214	3.83
24	2.37	206	3.97
207	2.37	218	4.23
G-34	2.40	22	4.37
240	2.47	221	4.53
223	2.47	201	5.33
23	2.50	20	6.17
208	2.50		
219	2.60		

ANOVA

	df	sos	ms	F
Between	55	154.34	2.81	20.25**
Within	112	15.52	0.14	
Total	167	169.86		

TABLE 27

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

Nickel

Station	Mean	Station	Mean
234	0.40	14	1.40
236	0.50	212	1.60
209	0.57	C	1.73
205	0.63	G-34	1.73
237	0.70	F	1.77
E	0.70	22	1.83
23	0.80	240	1.90
235	0.80	219	1.93
2	0.83	224	1.97
8	0.83	222	2.17
228	0.83	217	2.27
238	0.87	210	2.37
B	0.90	239	2.40
D	0.97	211	2.40
33	0.97	9	2.53
17	1.00	241	2.60
208	1.03	242	2.60
213	1.10	206	2.60
227	1.10	214	2.63
207	1.13	G-19	2.63
202	1.17	203	2.73
220	1.17	215	2.90
235	1.17	226	3.00
32	1.20	201	3.07
A	1.20	218	3.13
24	1.23	221	3.53
223	1.23	20	3.60

ANOVA

	df	sos	ms	F
Between	55	121.26	2.20	26.11**
Within	112	9.45	0.08	
Total	167	130.71		

TABLE 28

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

Copper

Station	Mean	Station	Mean
237	0.20	228	0.67
236	0.23	207	0.70
234	0.27	8	0.70
D	0.27	32	0.70
33	0.27	G-34	0.70
205	0.30	E	0.73
209	0.33	241	0.73
235	0.37	204	0.83
23	0.37	219	0.83
B	0.40	242	0.90
17	0.40	239	0.97
220	0.40	217	0.97
227	0.40	210	0.97
238	0.40	9	0.97
202	0.47	G-19	0.97
224	0.47	211	1.00
225	0.47	222	1.00
A	0.50	22	1.13
14	0.50	215	1.30
208	0.53	206	1.33
C	0.56	240	1.43
2	0.57	226	1.63
24	0.57	214	1.90
212	0.60	20	1.97
F	0.63	218	2.20
216	0.63	221	2.57
223	0.63	203	2.63
213	0.67	201	3.27

ANOVA

	df	sos	ms	F
Between	55	68.72	1.25	18.71**
Within	112	7.48	0.066	
Total	167	76.20		

TABLE 29
METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

Lead

Station	Mean	Station	Mean
238	0.40	239	2.40
23	0.85	B	2.50
235	1.03	22	2.60
D	1.05	223	2.60
236	1.10	9	2.67
202	1.20	F	2.80
234	1.25	E	2.83
237	1.25	211	2.97
209	1.30	210	3.13
14	1.33	241	3.13
208	1.43	215	3.27
32	1.60	C	3.27
33	1.77	20	3.30
225	1.77	222	3.33
220	1.90	226	3.37
A	1.90	219	3.37
207	1.93	217	3.50
204	2.00	224	3.57
24	2.03	242	3.73
212	2.20	G-19	4.07
227	2.20	206	4.20
205	2.23	201	5.03
228	2.30	214	5.23
240	2.30	218	5.60
8	2.35	221	6.20
216	2.37	203	6.73
2	2.40		
G-34	2.40		

ANOVA

	df	sos	ms	F
Between	53	247.53	4.67	5.09**
Within	99	90.69	0.92	
Total	152	338.22		

TABLE 30

METALS IN SEDIMENTS
Operation Mogul - Cruise 77-I
Duncan's Multiple Range Test
All Stations

Zinc

Station	Mean	Station	Mean
236	1.73	B	6.30
234	2.53	F	6.67
237	2.63	216	6.83
238	2.73	32	7.10
235	3.07	G-34	7.23
D	3.43	240	7.23
202	3.63	224	7.57
228	3.63	C	7.83
8	3.77	219	7.87
209	3.83	241	8.27
205	3.90	217	8.30
223	3.93	239	8.40
220	4.06	210	8.63
225	4.10	G-19	8.70
23	4.23	22	8.80
33	4.23	242	8.93
227	4.30	211	8.97
213	4.30	222	8.97
212	4.67	9	9.13
208	4.67	226	9.67
2	4.70	215	10.53
A	4.73	206	11.07
24	4.97	214	11.63
17	4.97	218	12.73
14	5.07	203	13.43
E	5.27	20	13.77
204	5.47	221	14.67
207	6.17	201	15.20

ANOVA

	df	sos	ms	F
Between	55	1784.73	32.45	33.80**
Within	112	107.51	0.96	
Total	167	1892.25		

TEMPORAL TRENDS OF METALS IN THE INTENSIVE GRID

Table 31 shows a summary of metal concentrations at stations in the intensive grid area common to the December 1975, August 1975 and February 1977 cruises. No consistent trends of increasing or decreasing concentrations are immediately apparent with any parameter. However, stations marked with an asterisk were significantly the highest in concentrations in the respective cruises, indicating these two clusters of stations show consistently elevated levels, and are probably the most severely impacted.

TABLE 31
METALS IN SEDIMENTS
Intensive Grid Area

Stations in Common			Pb			Cr		
Touchstone	Hotspot	Mogul	Touchstone	Hotspot	Mogul	Touchstone	Hotspot	Mogul
117		234	1.08		1.25	1.51		1.80
120	228	228	1.92		2.30	1.48		1.73
*122	201	201	5.53	4.13	5.03	2.93	5.57	5.33
124	202	202	3.01	3.23	1.20	1.40	4.73	1.80
133	235	235	2.73	0.93	1.03	1.46	2.60	2.33
*135	203	203	1.79	3.33	6.73	1.89	5.27	3.53
138	204	204	2.76	3.60	2.00	1.53	3.43	1.93
140	205	205	2.68	1.20	2.23	1.29	2.47	2.07
149	227	227	4.22	-	2.20	2.19	-	2.70
*152	206	206	5.75	4.03	4.20	2.60	4.20	3.97
154	207	207	2.67	1.43	1.93	1.91	2.33	2.37
156	208	208	4.11	<0.5	1.43	2.18	2.67	2.50
165	209	209	-	<0.5	1.30	1.94	1.60	1.90
167	-	210	3.16	-	3.13	2.54	2.40	3.30
170	211	211	5.14	1.93	2.97	2.58	3.97	3.50
172	212	212	3.93	1.70	2.20	2.07	2.90	2.67
181	213	213	2.73	<0.5	<0.5	2.24	2.20	1.97
184	214	214	3.28	1.80	5.23	3.45	4.03	3.83
*186	215	215	5.73	1.90	3.27	3.12	4.43	3.57
188	216	216	3.12	2.70	2.37	2.96	3.57	2.27
	217	217		0.80	3.50		2.47	3.13
	*218	218		2.30	5.60		6.07	4.23
	219	219		1.80	3.37		3.87	2.60
	220	220		0.45	1.90		1.80	1.33
	*221	221		1.67	6.20		4.23	4.53
	222	222		1.60	3.33		4.00	3.00
	223	223		2.00	2.60		3.07	2.47
	224	224		1.00	3.57		2.57	2.33
	225	225		3.37	1.77		2.87	2.17
	*226	226		3.70	3.37		4.53	3.53

TABLE 31 (cont.)

METALS IN SEDIMENTS

Intensive Grid Area

Stations in Common			Ni			Zn		
Touchstone	Hotspot	Mogul	Touchstone	Hotspot	Mogul	Touchstone	Hotspot	Mogul
117		234	0.15		0.40	2.21		2.53
120	228	228	0.45		0.93	2.47		3.63
122	201	201	2.33	1.67	3.07	7.11	12.83	15.20
124	202	202	0.86	1.67	1.17	4.02	11.50	3.63
133	235	235	0.39	<0.1	0.80	3.14	3.43	3.07
135	203	203	1.40	1.37	2.73	3.50	9.87	13.43
138	204	204	0.67	1.60	1.37	3.24	9.23	5.47
140	205	205	0.92	0.30	0.63	2.45	2.43	3.90
149	227	227	0.28	-	1.10	.65	-	4.30
152	206	206	1.00	1.57	2.60	2.40	8.87	11.07
154	207	207	1.10	0.25	1.13	3.24	3.03	6.17
156	208	208	1.59	0.30	1.03	3.91	2.73	4.67
165	209	209	0.72	0.45	0.57	3.00	2.90	3.83
167	-	210	1.23	0.24	2.37	3.35	3.27	8.63
170	211	211	1.82	1.33	2.40	5.67	7.73	8.97
172	212	212	1.31	0.67	1.33	4.25	4.50	4.67
181	213	213	1.57	0.47	1.10	4.48	2.77	4.30
184	214	214	1.54	1.33	2.63	5.89	7.87	11.63
186	215	215	2.50	1.70	2.90	7.79	8.40	10.53
188	216	216	1.79	1.17	1.60	4.32	6.47	6.83
	217	217		0.30	2.27		3.17	8.30
	218	218		2.43	3.13		11.60	12.73
	219	219		1.13	1.93		7.37	7.87
	220	220		0.40	1.17		2.53	4.06
	221	221		1.80	3.53		10.50	14.67
	222	222		1.37	2.17		7.20	8.97
	223	223		0.90	1.23		5.47	3.93
	224	224		0.33	1.97		2.57	7.57
	225	225		0.50	1.17		3.27	4.10
	226	226		1.77	3.00		9.03	9.67

TABLE 31 (cont.)
METALS IN SEDIMENTS
Intensive Grid Area

Stations in Common			Cu	
Touchstone	Hotspot	Mogul	Touchstone	Mogul
117		234	<0.10	0.27
120	228	228	0.15	0.67
122	201	201	1.19	3.27
124	202	202	0.42	0.47
133	235	235	0.41	0.37
135	203	203	0.30	2.63
138	204	204	0.38	0.83
140	205	205	0.35	0.30
149	227	227	0.39	0.40
152	206	206	0.49	1.33
154	207	207	0.34	0.70
156	208	208	0.45	0.53
165	209	209	<0.10	0.33
167	-	210	<0.10	0.97
170	211	211	0.61	1.00
172	212	212	0.52	0.60
181	213	213	0.53	0.67
184	214	214	<0.10	1.90
186	215	215	1.23	1.30
188	216	216	0.36	0.63
	217	217		0.97
	218	218		2.20
	219	219		0.83
	220	220		0.40
	221	221		2.57
	222	222		1.00
	223	223		0.63
	224	224		0.47
	225	225		0.47
	226	226		1.63

DISTRIBUTION OF INFAUNA IN INTENSIVE GRID

Previous reports (hearing testimony, City of Philadelphia; ocean dumping permit hearing, Georgetown, Delaware, April 1976) have indicated changes in the benthic infaunal community as a function of ocean dumping activity. These conclusions were based on observations of data from the regional wide area monitoring (historical) stations.

More detailed examination of data in the intensive sampling (grid) areas associated with the high organic carbon and metal deposits is currently in progress. Figures 67 through 85 show the distribution of the dominant organisms from the December 1975 cruise (Operation Touchstone). Numbers shown are the mean of three replicates.

Visual inspection of the data indicate the distribution of the archiannelid *Protodrilus* did not appear to be affected by any of the parameters measured. Similarly the nematode distribution showed no obvious positive or negative associations with the "clean" or "dark" areas.

The polychates showed a wide range of response. *Goniadella gracilis*, *Parapionsyllis longicirrata*, *Praxilella "B"*, *Sphaerosyllis erinaceus*, and *Aglaophamus circinata* were intolerant of the materials deposited. *Stauronereis caecus* was apparently indifferent. *Spiophanes bombyx*, *Minuspio japonica*, *Exogone hebes*, and *Potomilla neglecta* population densities were apparently stimulated by the inputs to this habitat. Within some polychaete general *Lumbrinereis impatiens* was stimulated while *Lumbrinereis acuta* was intolerant of these conditions. *Aricidea jeffreysii* was intolerant, while *Aricidea sueria* and *Aricidea neosuecia* were apparently indifferent.

Of the amphipods dominating this environment, Byblis serrata and Trichophoxis epistomis seemed to be indifferent, while Ampelisca vadorum populations were stimulated in the high organic areas.

Preliminary statistical examination of these data indicated the benthic populations were not normally distributed, but fitted a negative binomial distribution. Consequently a nonparametric statistical method, Spearman's rank correlation, was selected to determine whether the apparent distributions were in fact statistically sound (Table 32).

The polychaete, Spiophanes bombyx, was apparently stimulated in numbers in the areas of high organic carbon at this time, as indicated by positive and significant correlation coefficient. Mean grain size was not significant in its distribution, but the percent fines was correlated at a lesser level.

Sphaerosyllis erinaceus and Lumbrinereis acuta were significantly excluded from the areas of high organic carbon and nickel, were independent of mean grain size, but were negatively correlated with percent fine fraction. Goniadella gracilis was excluded from the high organic carbon and nickel areas, and was negatively correlated with mean phi and percent fine fractions.

Data analyses are continuing on this aspect, but the indications to date are that sewage sludge disposal is significantly altering the distribution of the benthic infauna, causing aberrant increases of some opportunistic species, and lethal to the pollution sensitive species.

TABLE 32

Correlation of Benthic Infauna with Environmental Parameters

Spearman's Rank Correlation

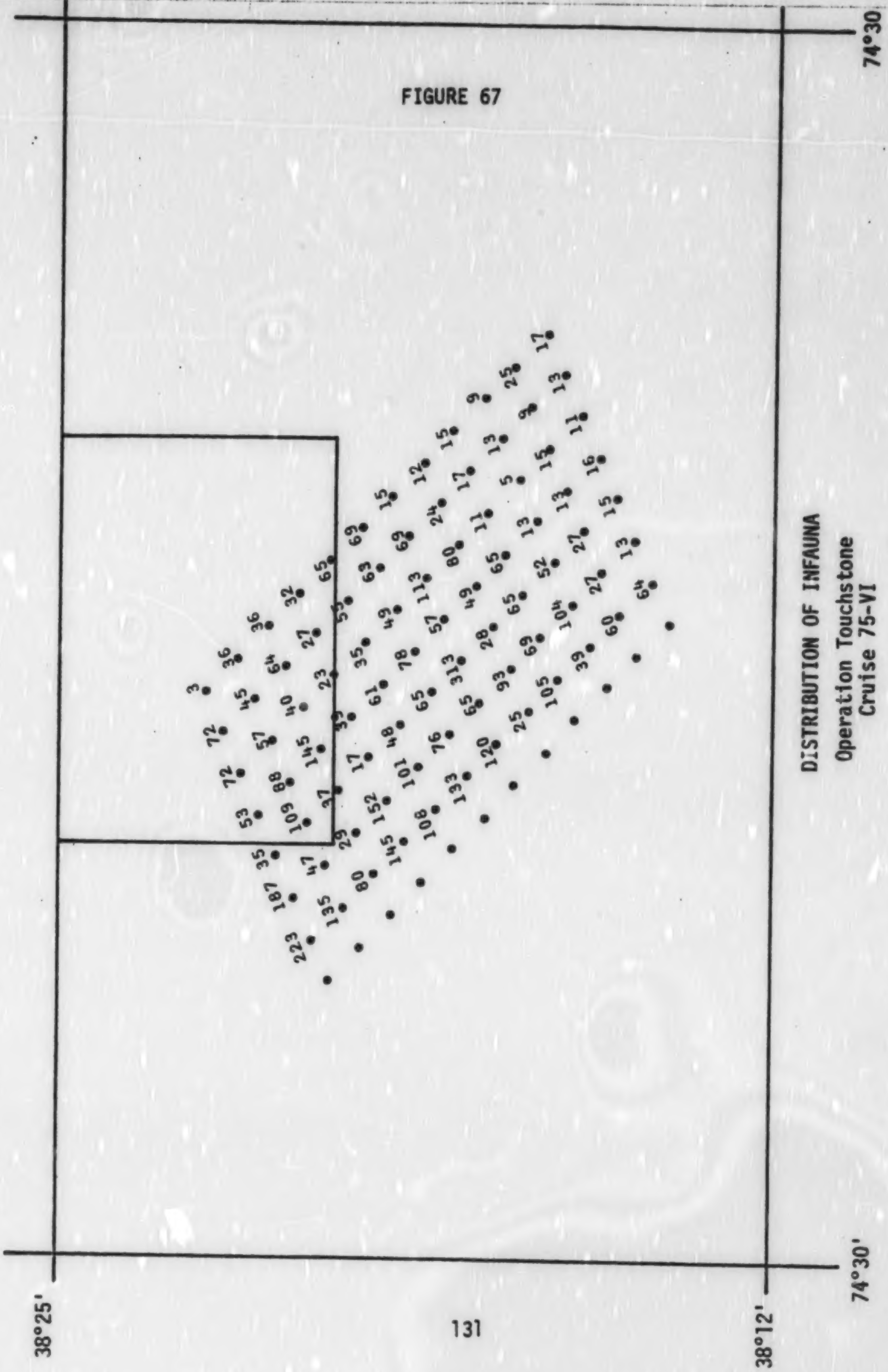
r_s,t

	Mean ø	% Fines	TOC	Ni
Spiophanes bombyx	0.44	0.58	0.54	0.67
	1.73	2.52	5.85**	5.20**
Goniadella gracilis	-0.56	0.47	-0.62	-0.67
	2.38*	1.89*	8.99**	5.20**
Sphaerosyllis erinaceus	0.02	-0.62	-0.50	-0.49
	0.07	2.79**	6.32**	6.46**
Lumbrinereis acuta	-0.22	-0.71	-0.52	-0.76
	0.79	3.50**	5.51**	14.04**

* Significant $p < 0.05$

** Significant $p < 0.01$

FIGURE 67


38°25'
38°12'
74°30'
74°30
3
36
36
32
65
69
15
12
15
9
25
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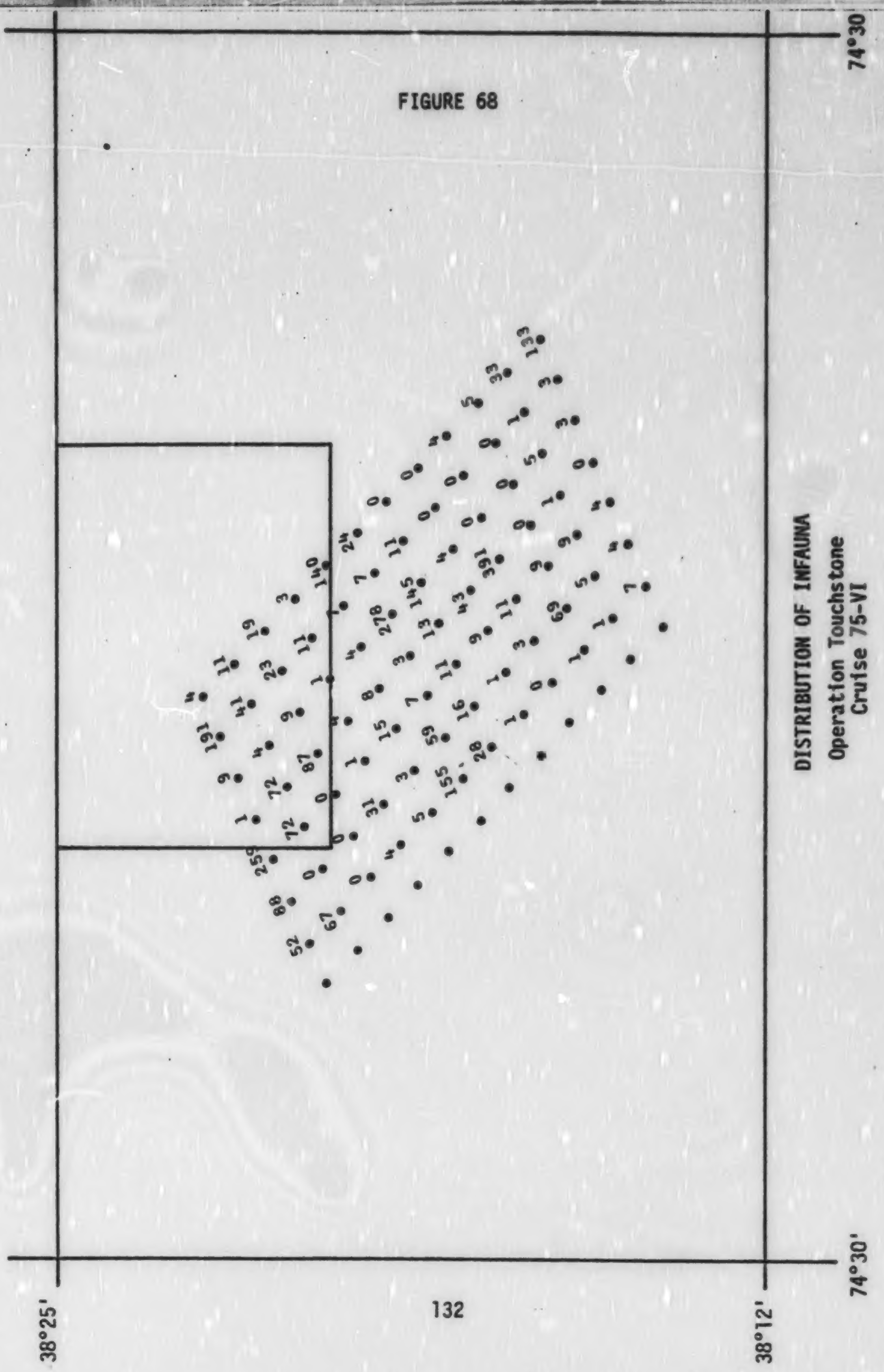
72
45
64
27
55
63
69
24
17
13
9
13
72
57
40
23
35
49
113
80
11
5
15
11
53
88
145
39
61
78
57
49
65
13
13
16
35
109
37
17
48
65
313
28
65
52
27
15
187
47
29
152
101
76
65
93
69
104
27
13
223
135
80
145
108
133
120
25
105
39
60
64

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Protodrilus sp.

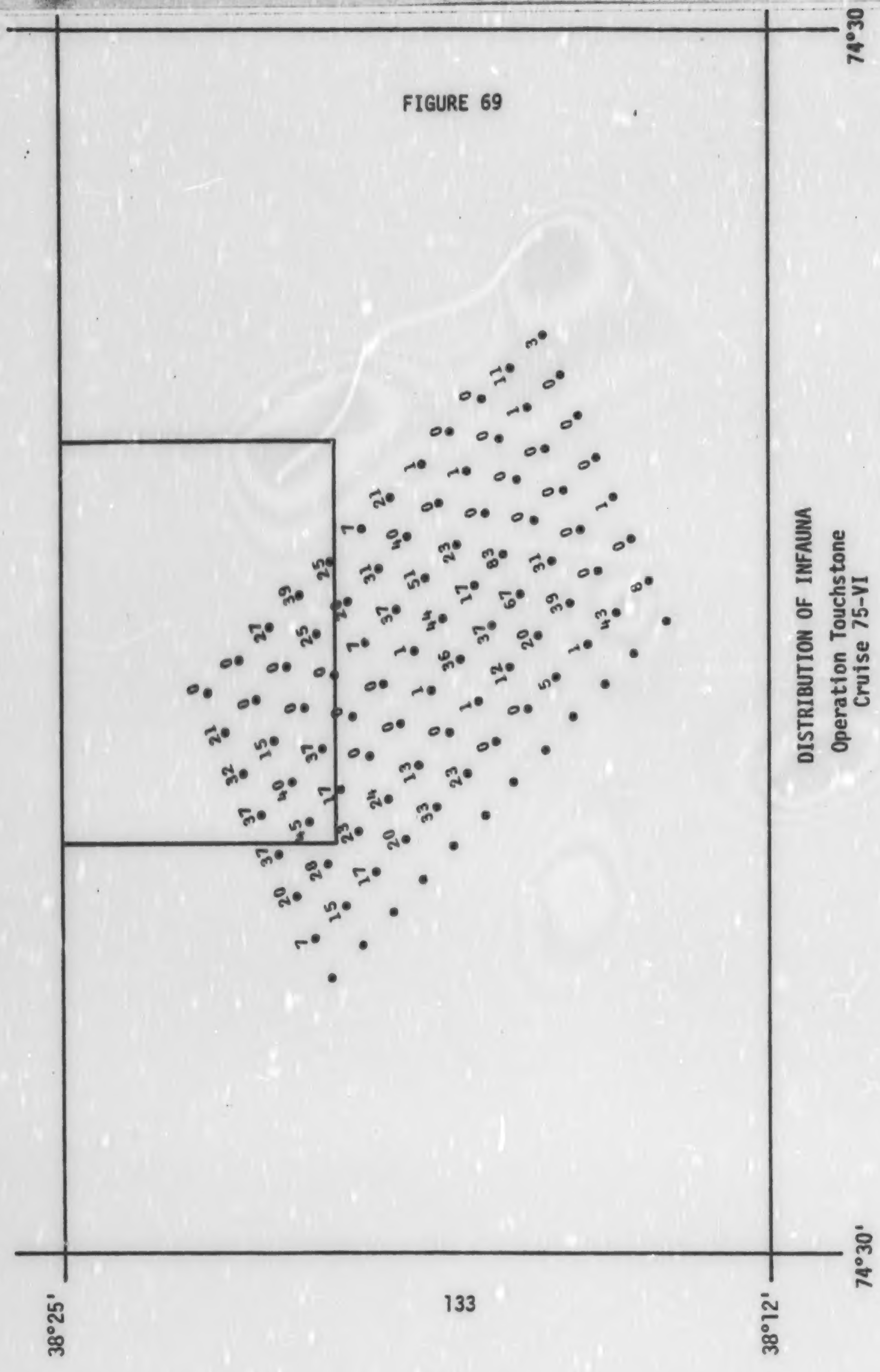
FIGURE 68


74°30'
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Nematodes

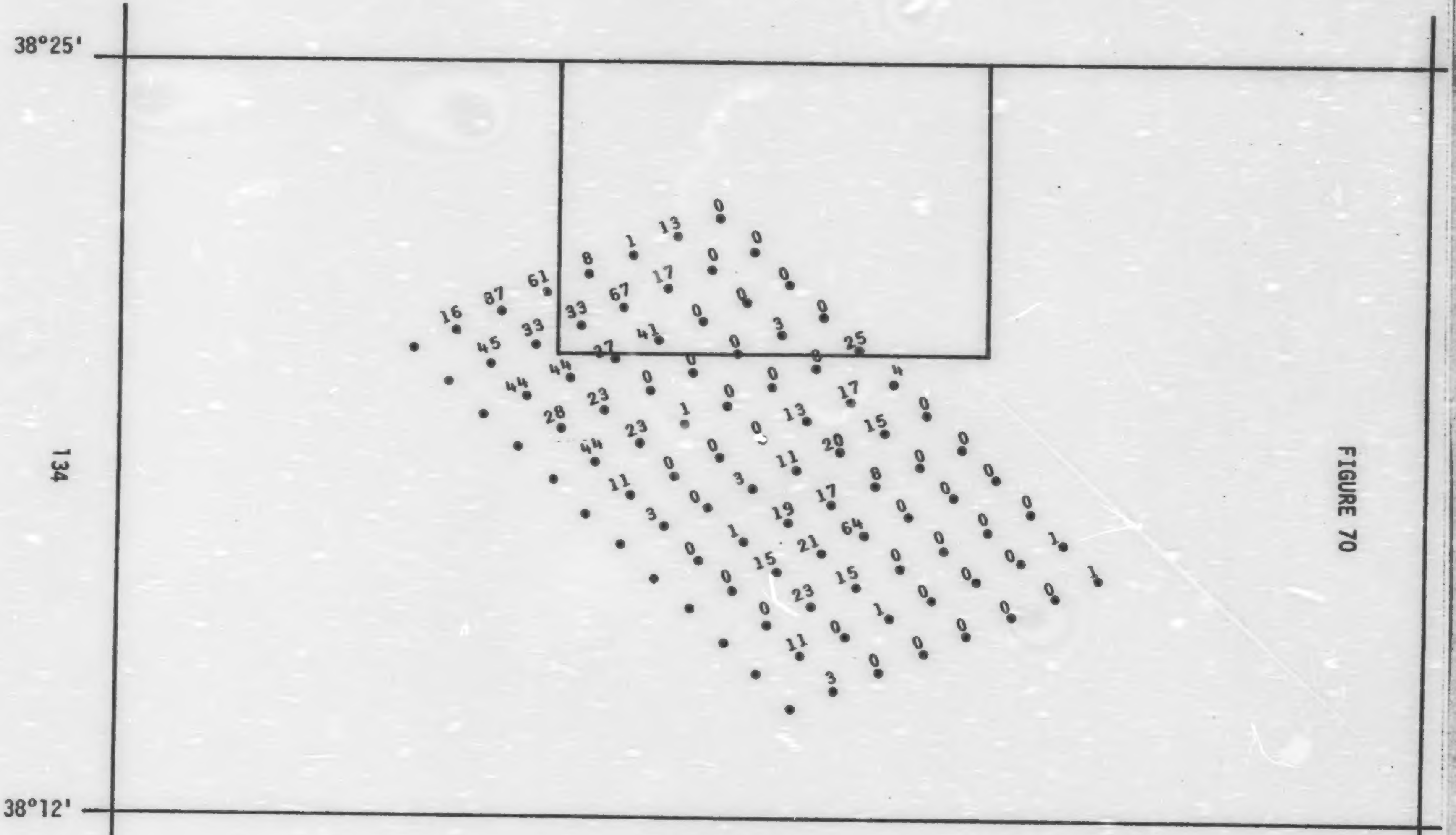
FIGURE 69


74°30
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Goniadella gracilis

FIGURE 70


38°25'
38°12'
74°30'
74°30
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0
0
0
25
4
0
0
0
0
1
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0
3
0
17
15
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0
0
1
17
0
0
0
13
20
8
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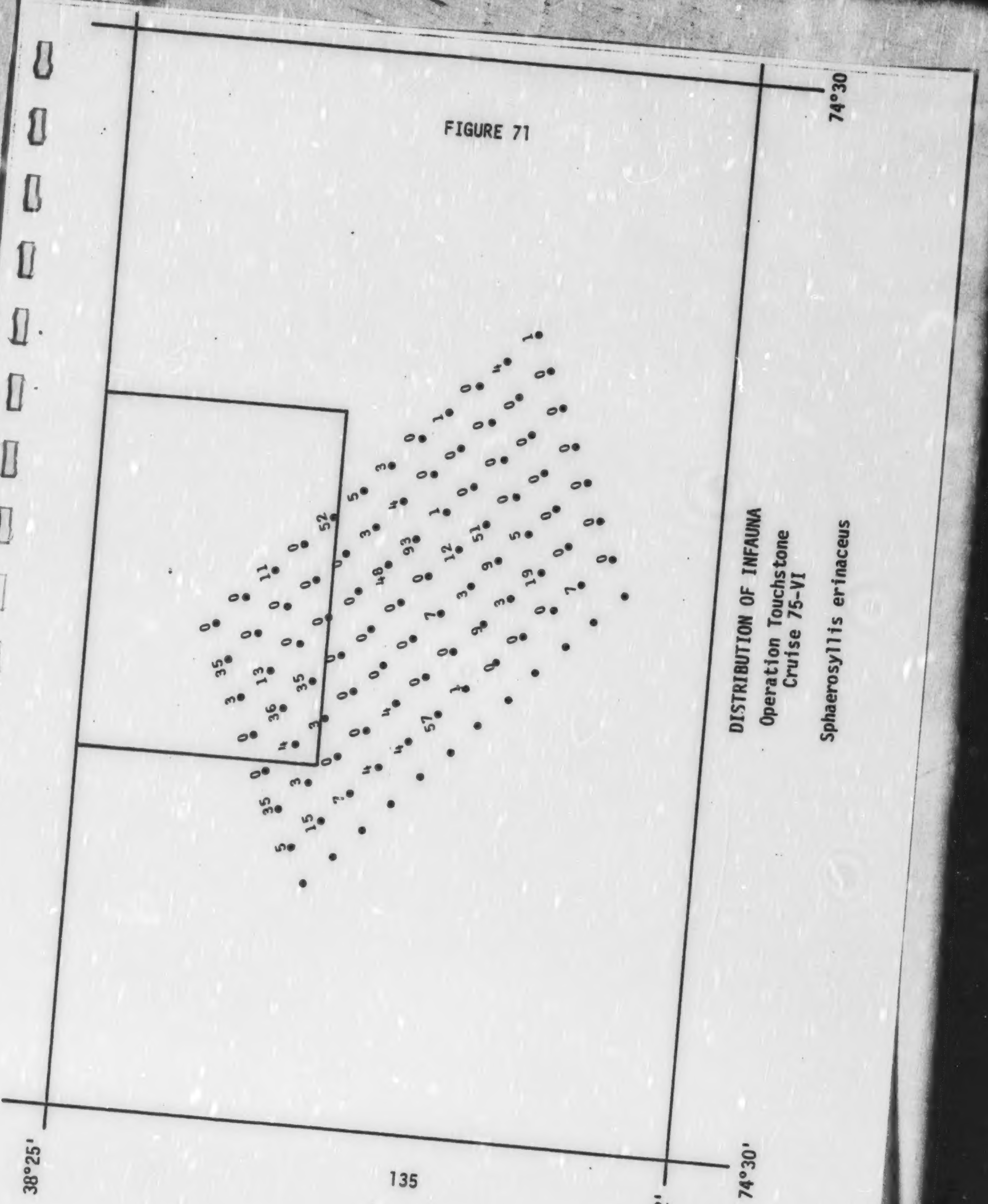
0
0
0
8
67
41
0
0
0
11
17
64
0
0
0
61
33
27
0
1
0
3
19
21
15
1
0
87
33
44
23
23
0
0
1
15
23
0
0
16
45
44
28
44
11
3
0
0
0
11
3

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Parapionosyllis longicirrata

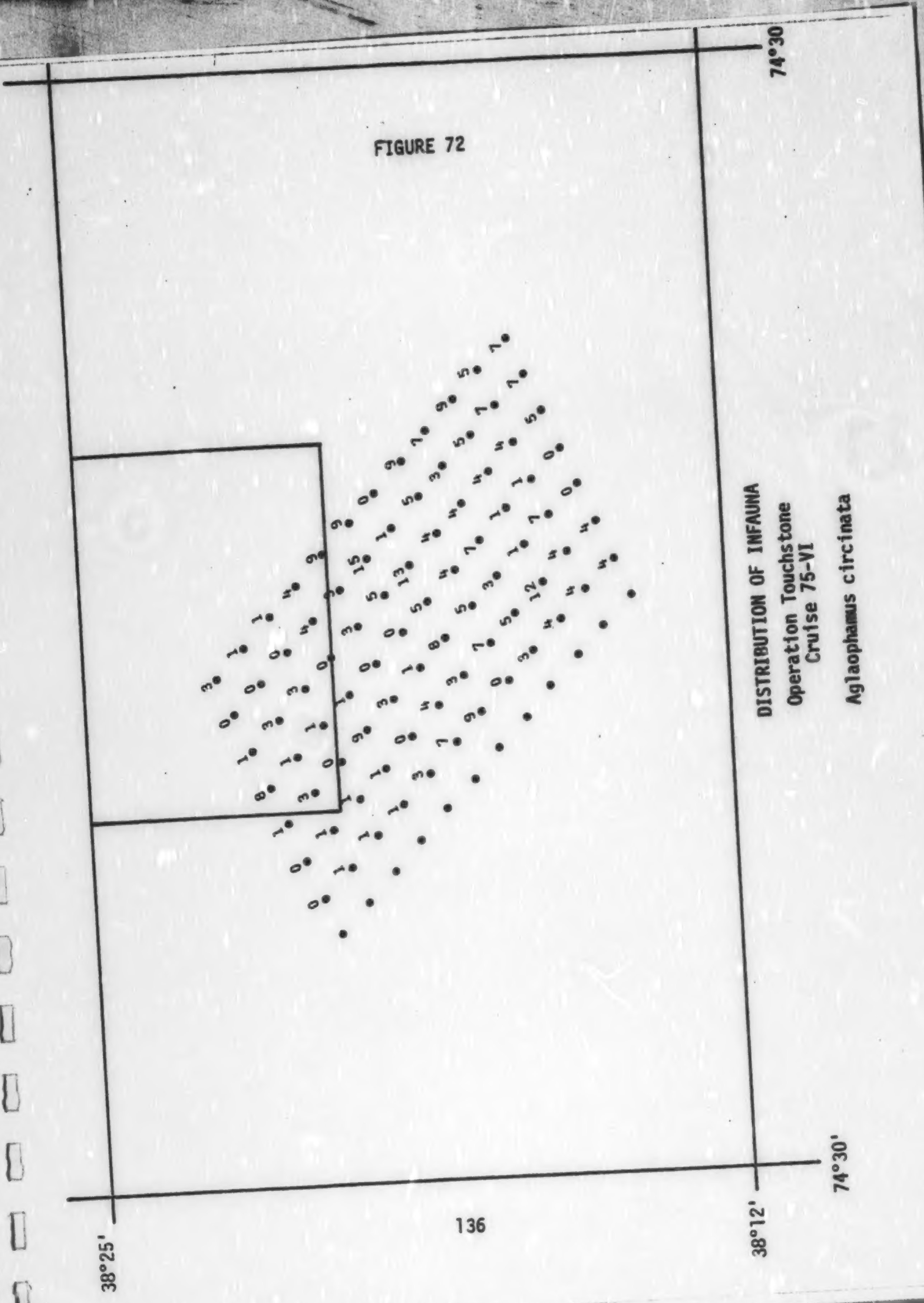
FIGURE 71


74°30
38°25'
38°12'
74°30'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Sphaerosyllis erinaceus

FIGURE 72



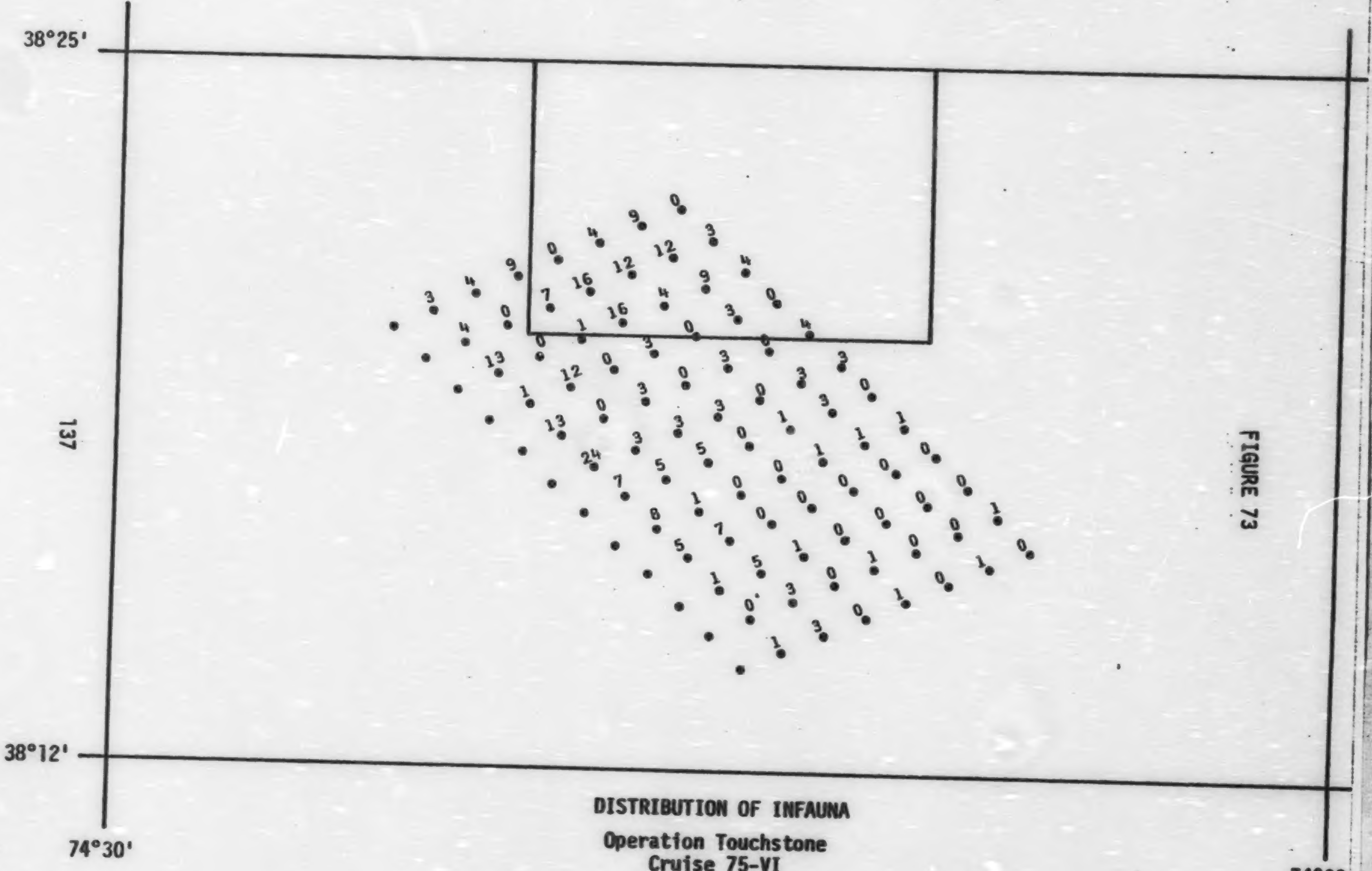
DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Aglaophamus circinata

74°30
74°30'
38°25'
38°12'

FIGURE 73

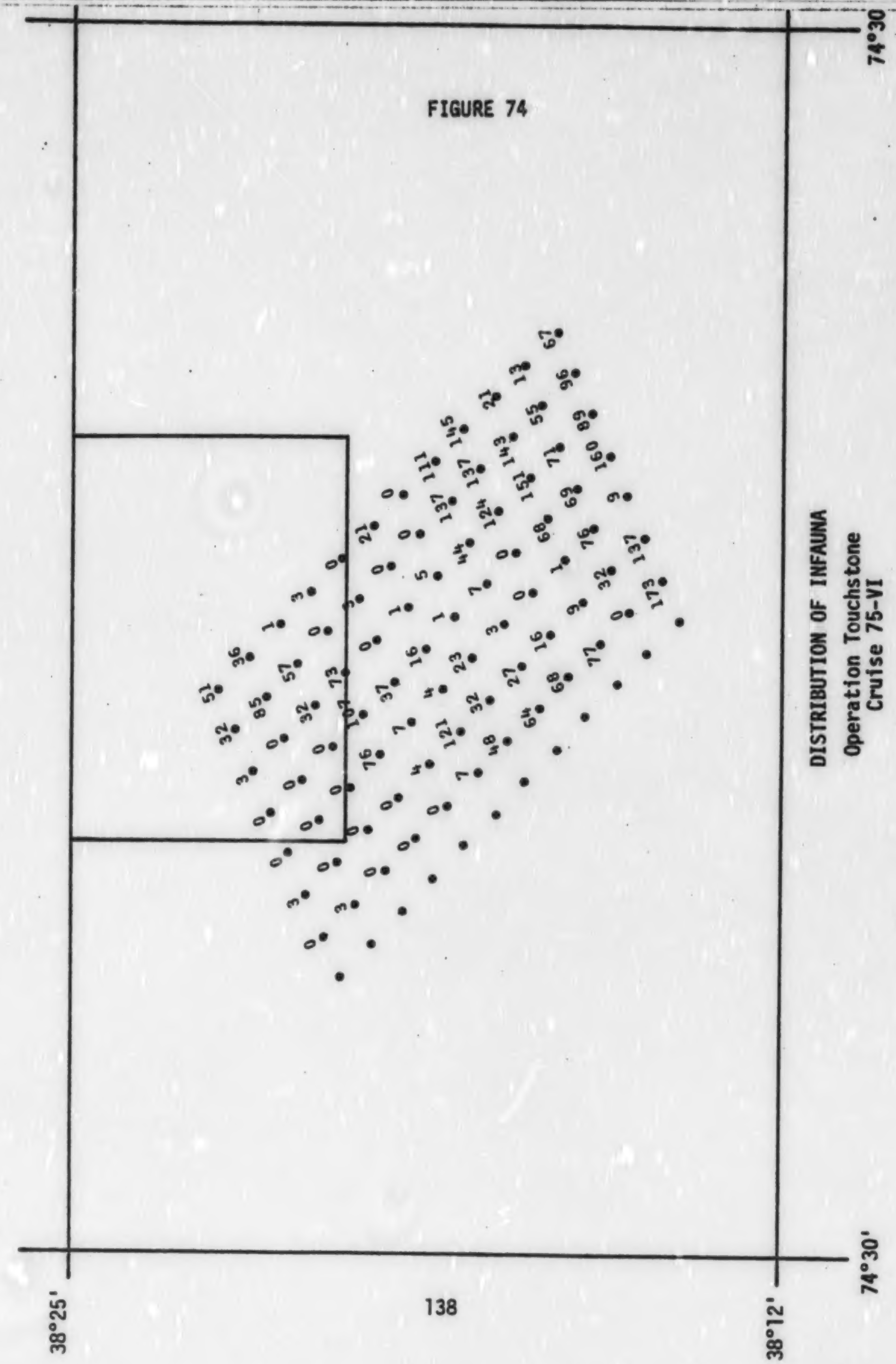

38°25'
38°12'
74°30'
74°30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Stauronereis caecus

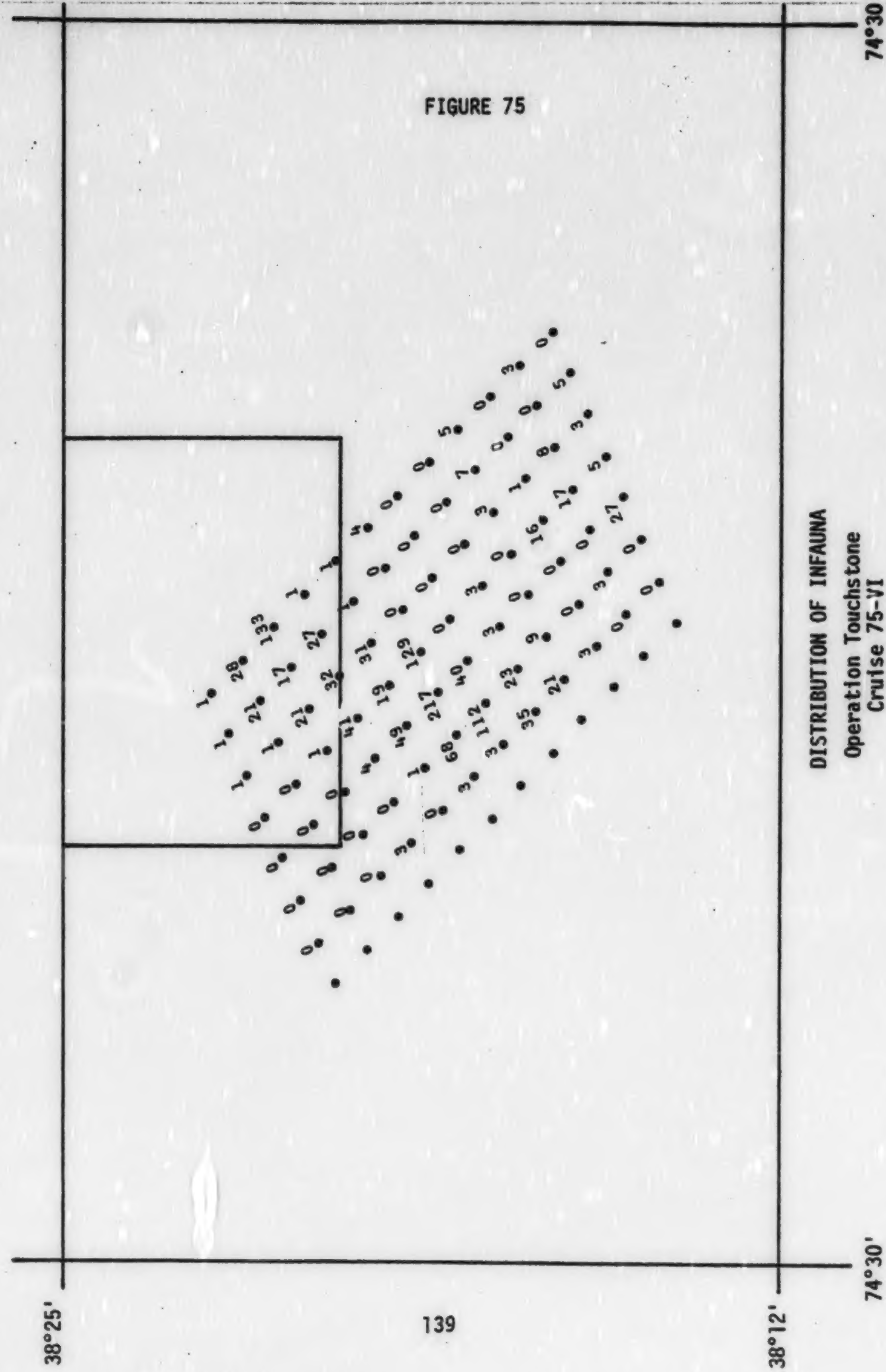
FIGURE 74


74°30
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Spiophanes bombyx

FIGURE 75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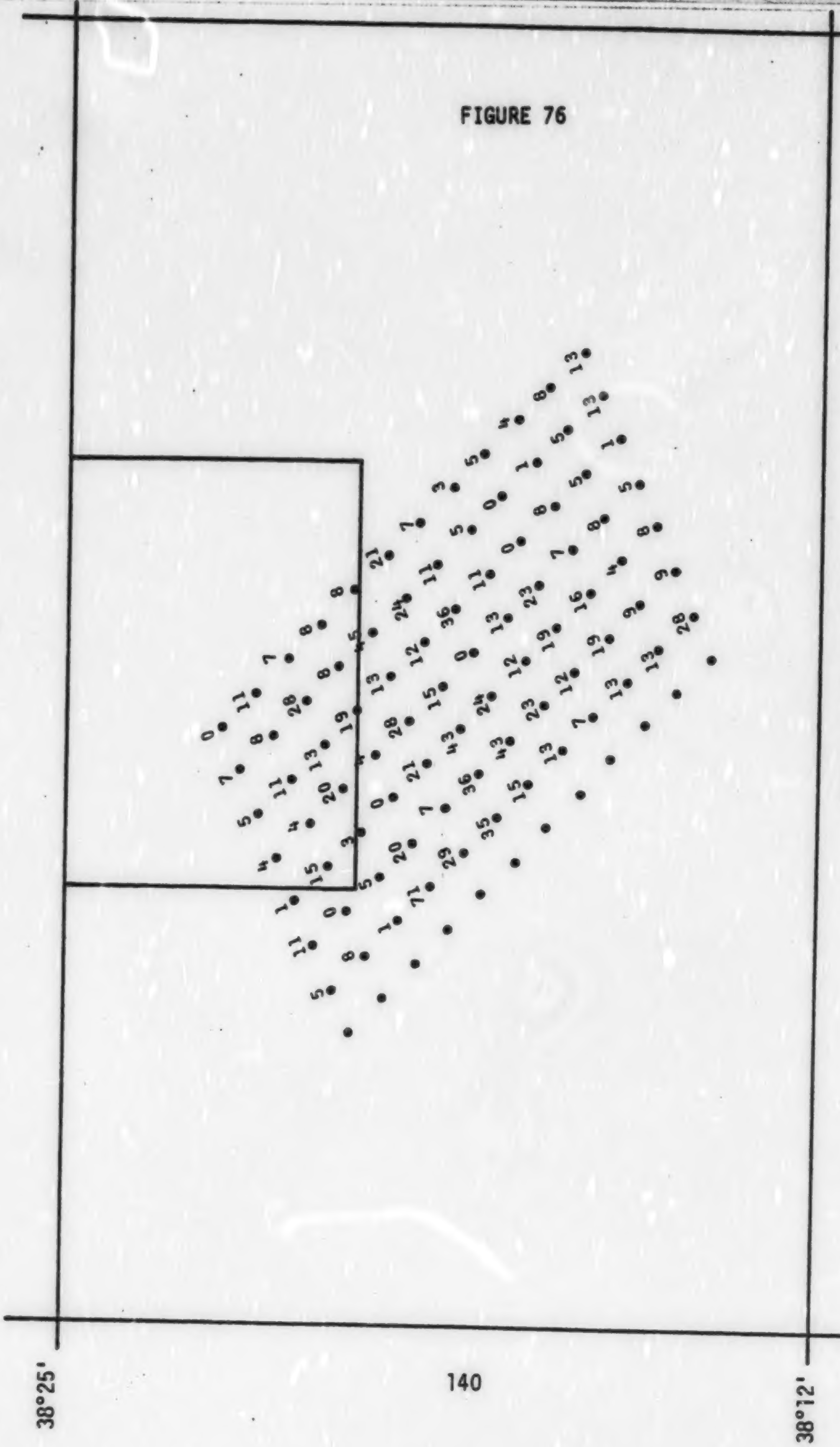
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Minuspio Japonica

FIGURE 76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38°12'
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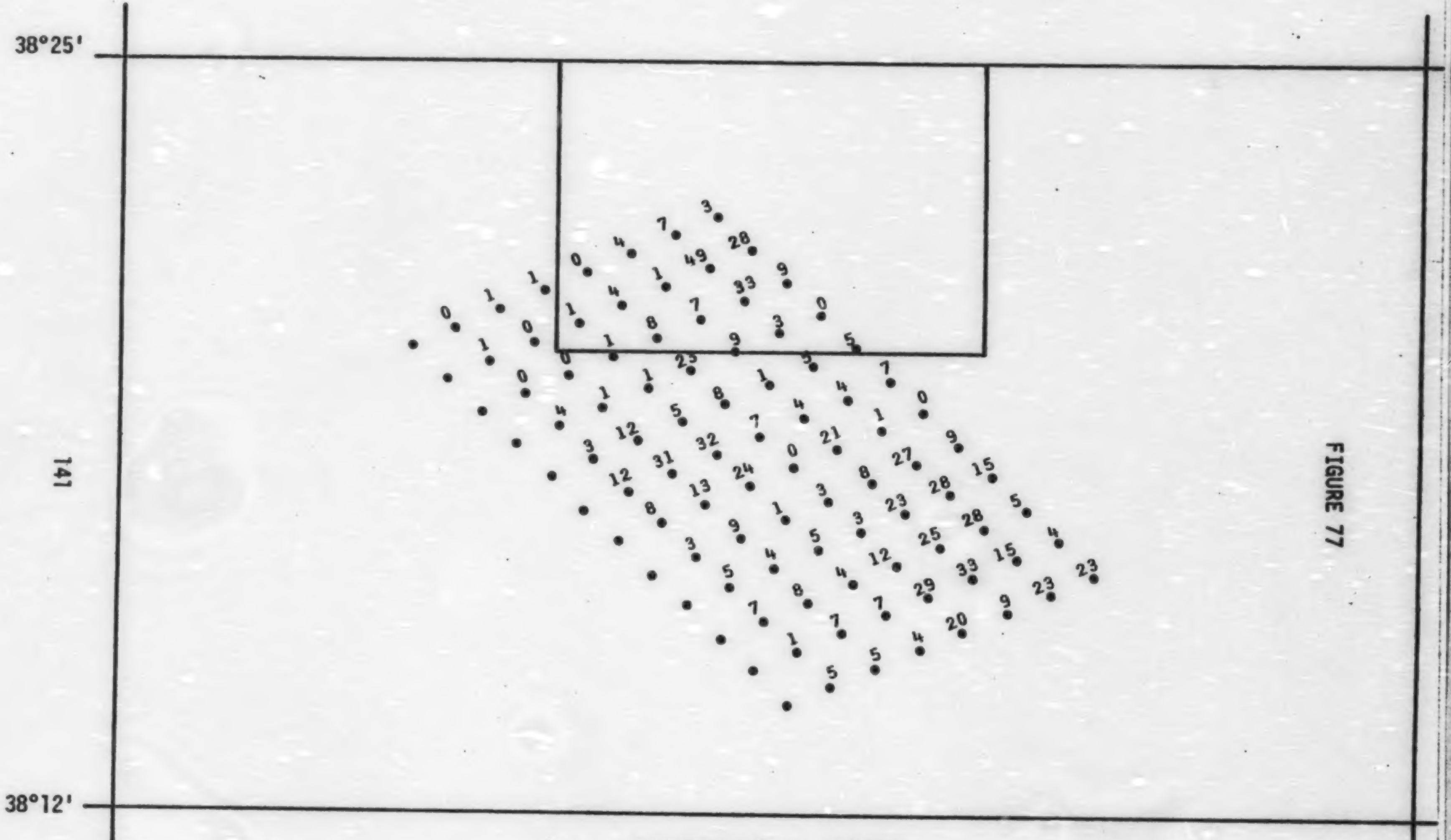
7 8 28 8 5 24 11 5 0 1 5 13
5 11 13 19 13 12 36 11 0 8 5 1
4 4 20 4 28 15 0 13 23 7 8 5
1 15 3 0 21 43 24 12 19 16 4 8
11 0 5 20 7 36 43 23 12 19 9 9
5 8 1 71 29 35 15 13 7 13 13 28

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Exogone hebes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74°30
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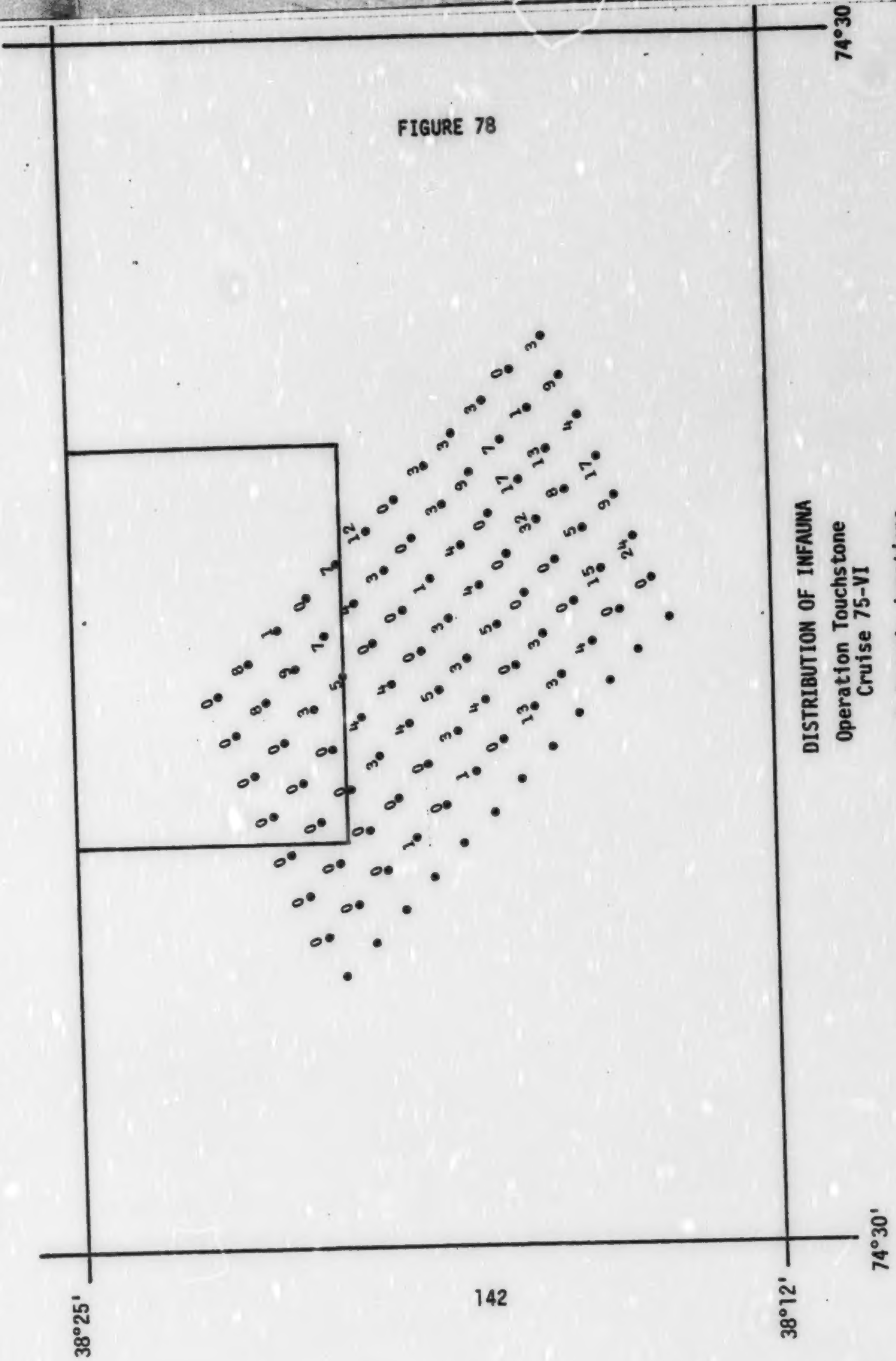
7 49 33 3 5 4 1 27 28 28 15 23
4 1 7 9 1 4 21 8 23 25 33 9
0 4 8 25 8 7 0 3 3 12 29 20
1 1 1 1 5 32 24 1 5 4 7 4
1 0 0 1 12 31 13 9 4 8 7 5
0 1 0 4 3 12 8 3 5 7 1 5

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Potamilla neglecta

FIGURE 78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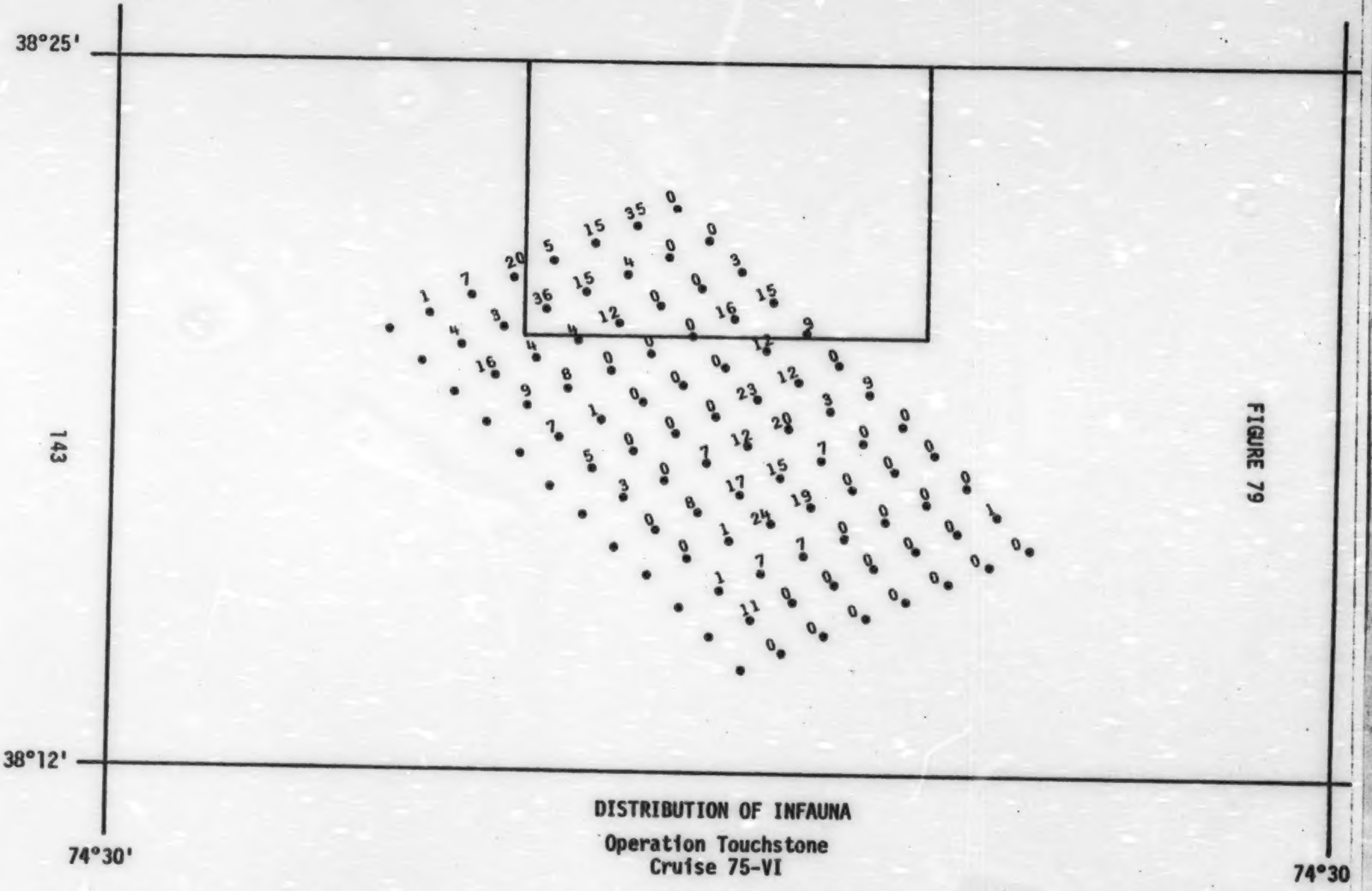
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Lumbrinereis impatiens

FIGURE 79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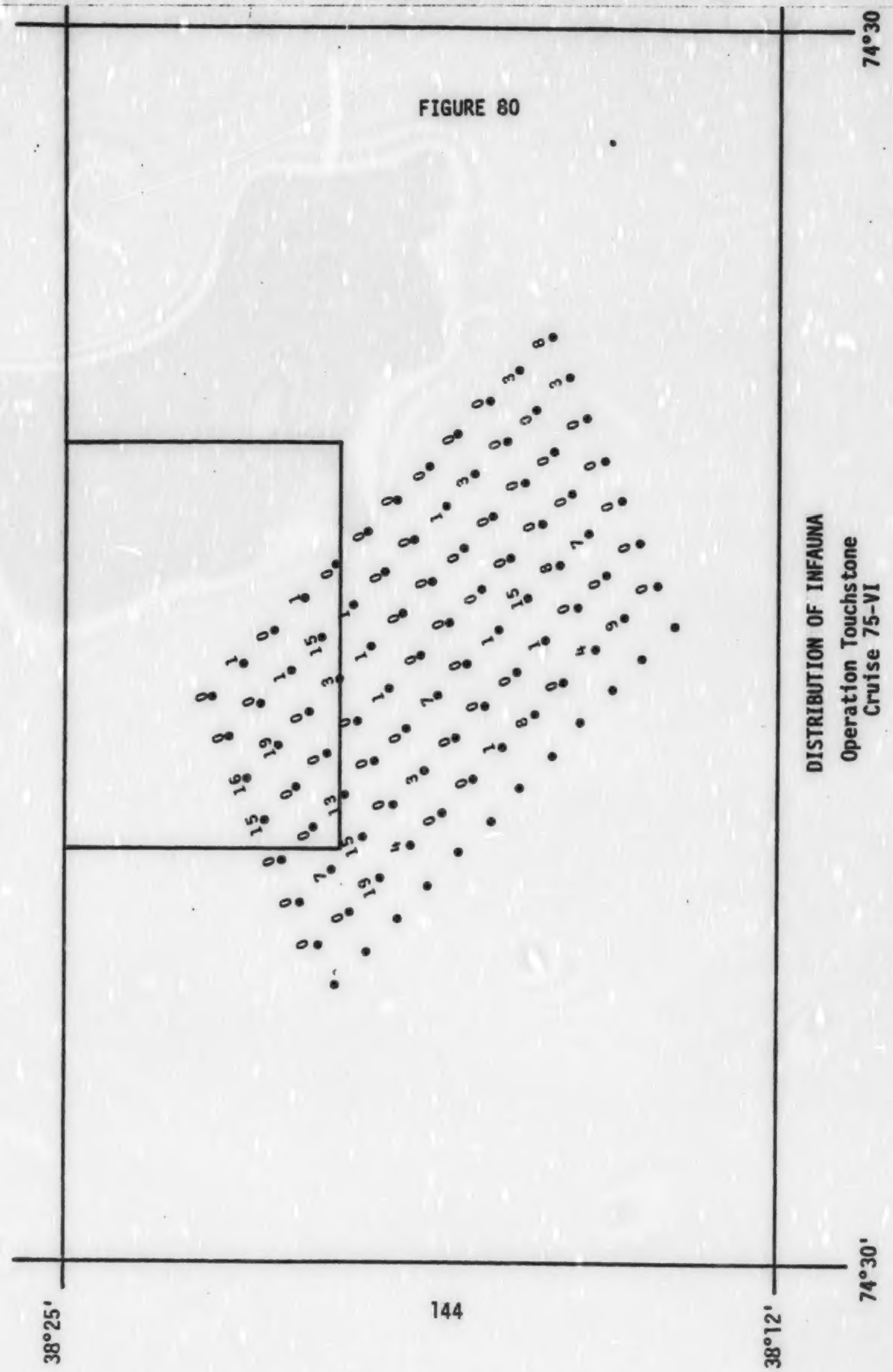
38°12'
74°30'
74°30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Lumbrinereis acuta

FIGURE 80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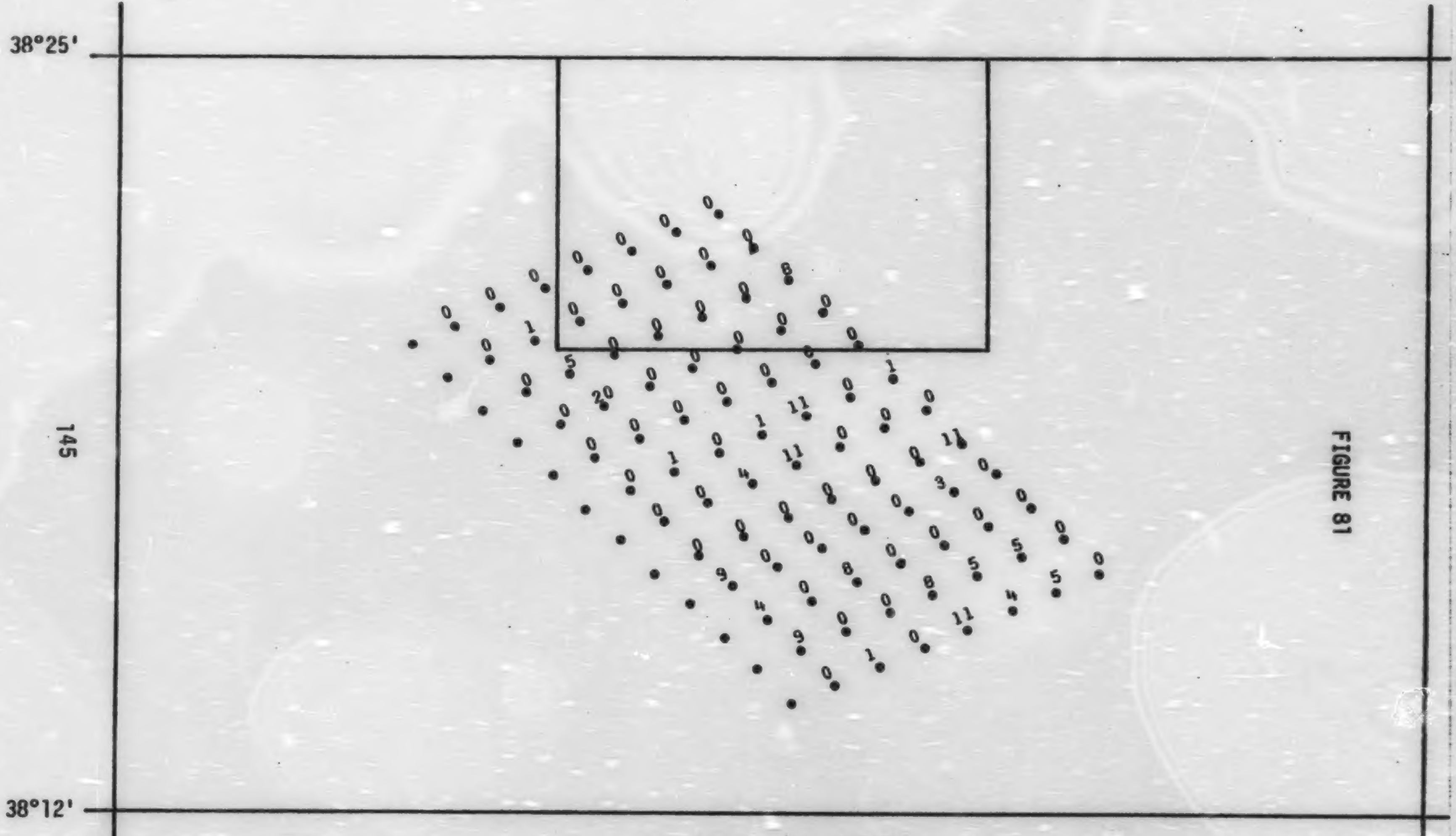
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI
Aricidea jeffreysii

FIGURE 81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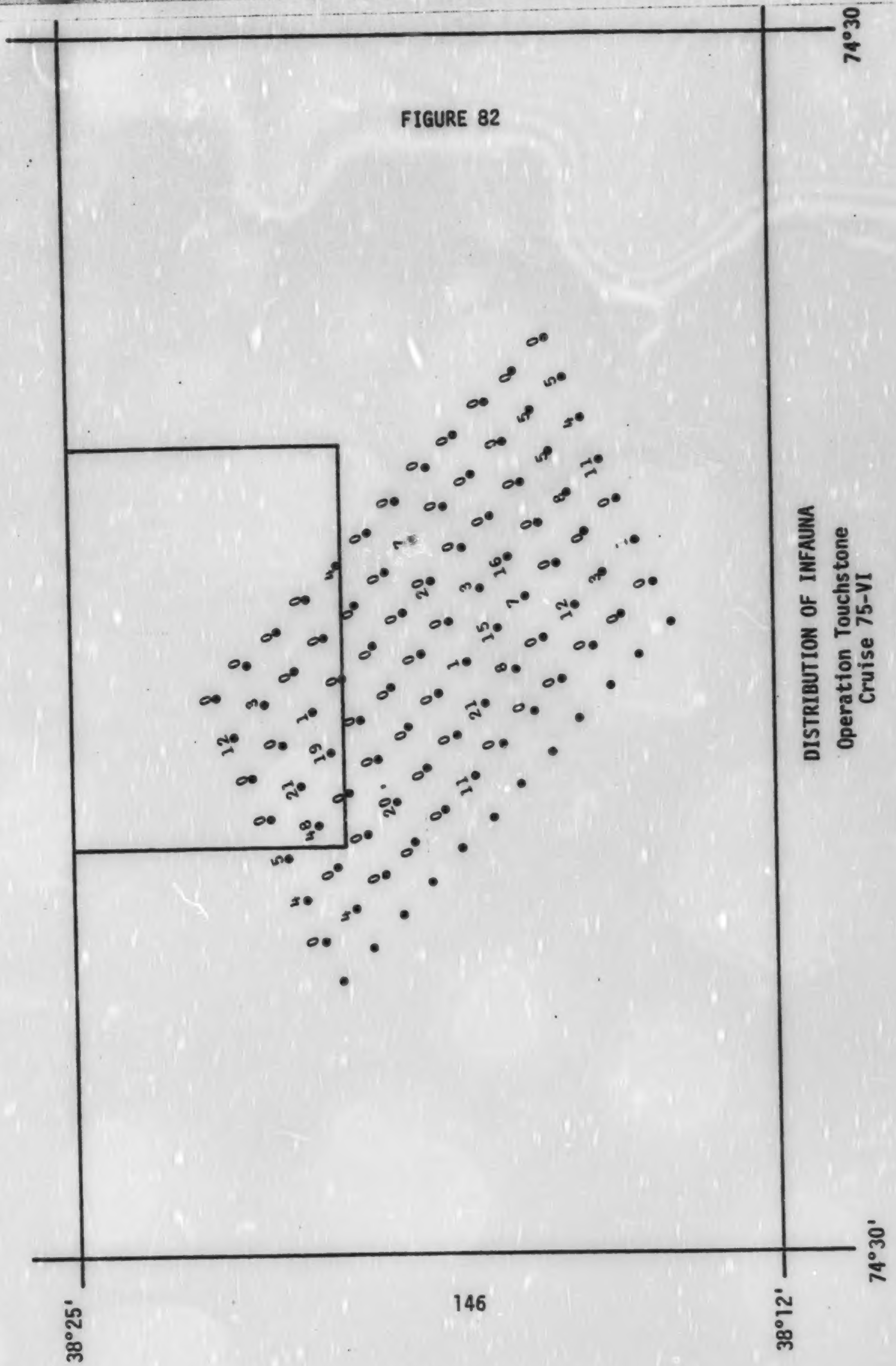
38°12'
74°30'
74°30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Aricidea suecia

FIGURE 82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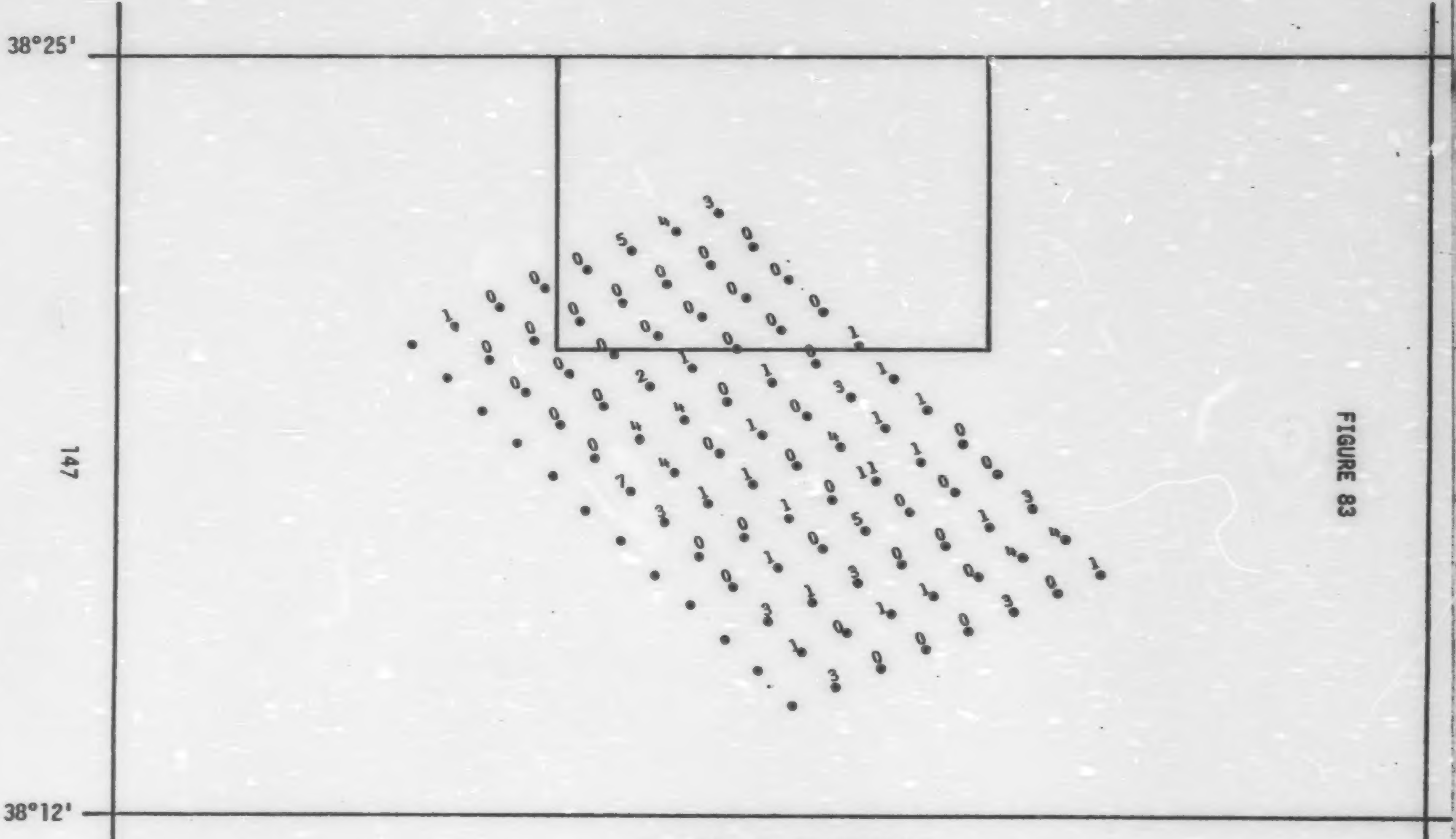
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Aricidea neosuecia

FIGURE 83


38°25'
38°12'

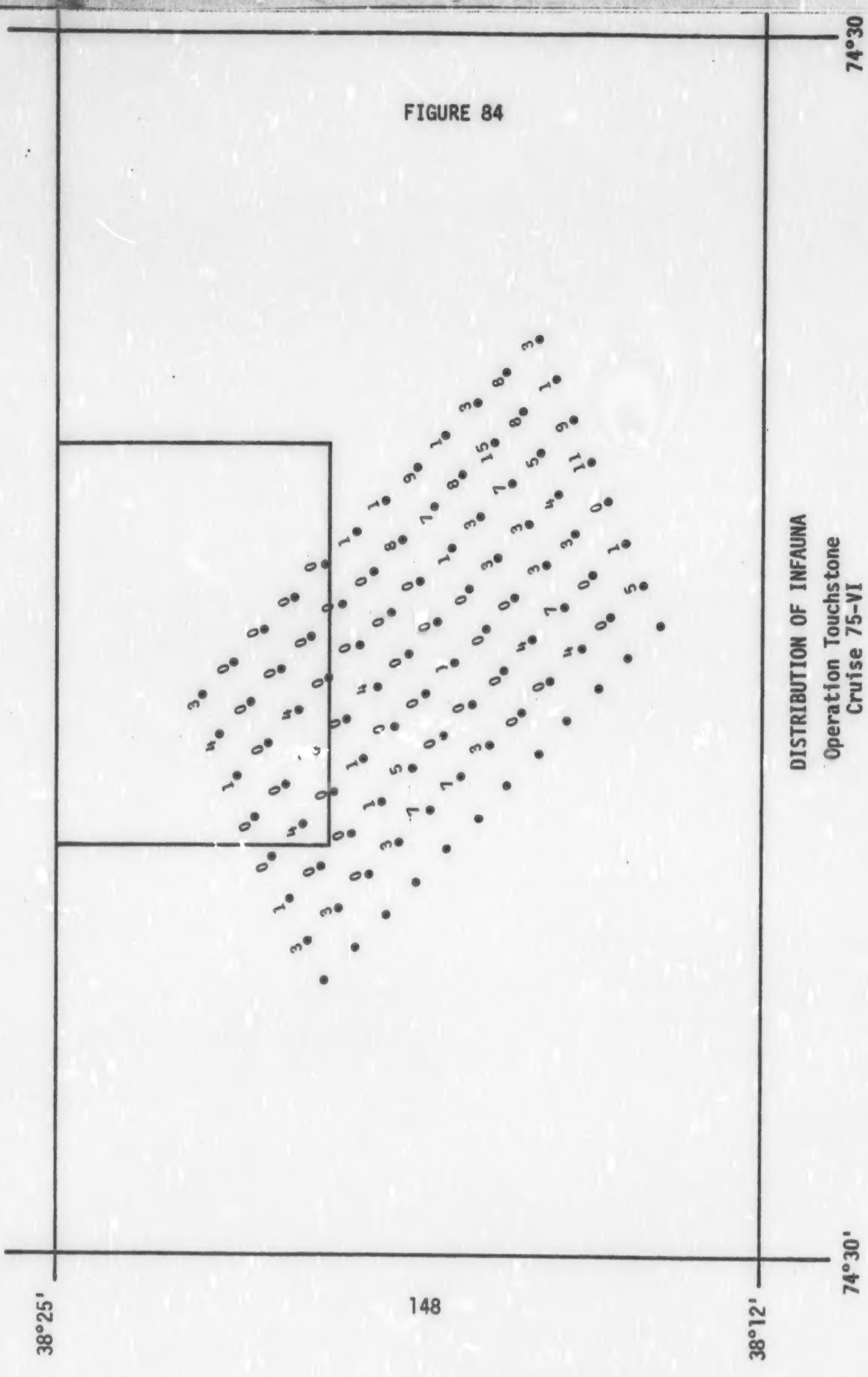
74°30'
74°30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Byblis serrata

FIGURE 84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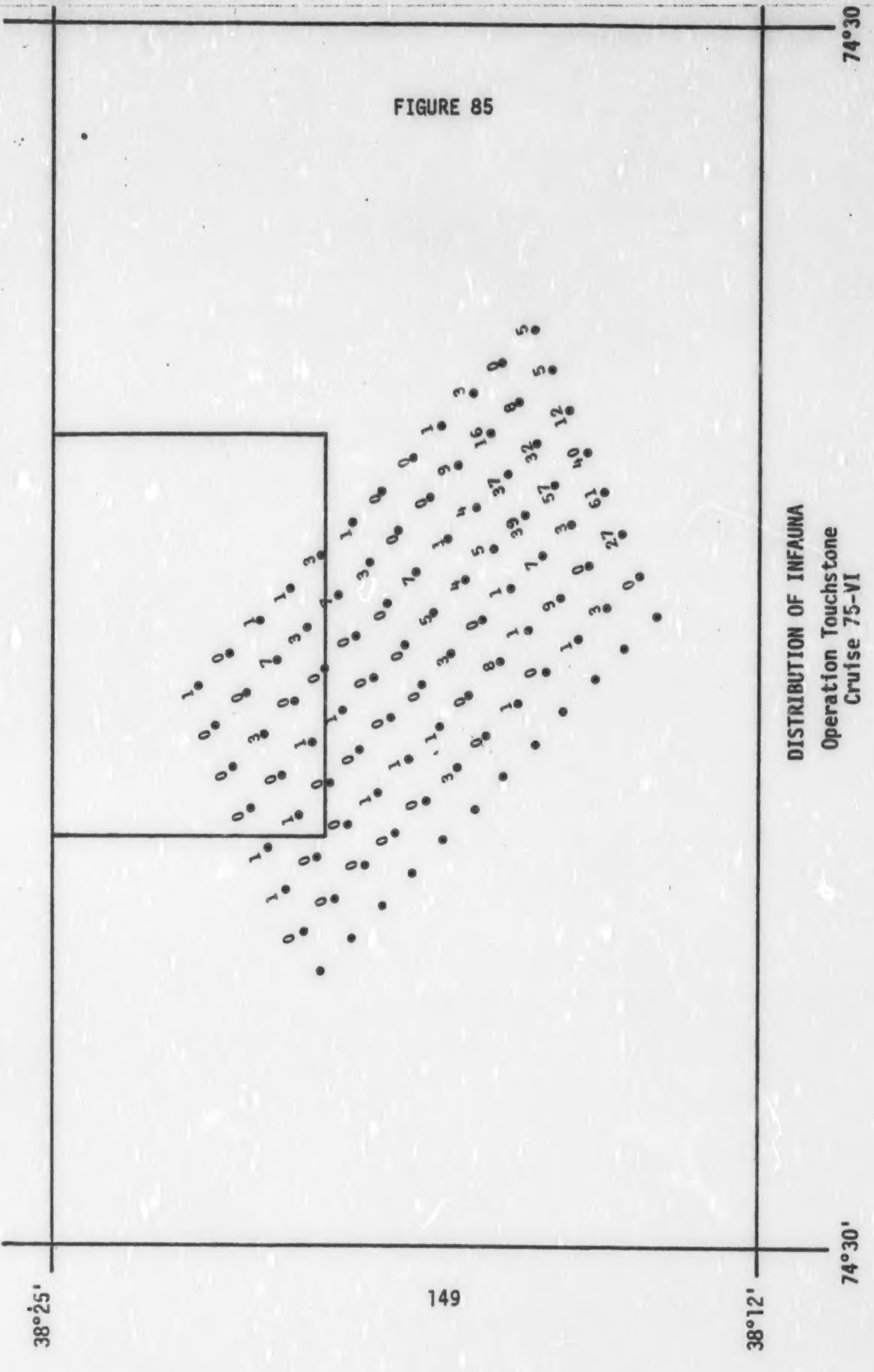
74°30'
38°25'
38°12'
3 8 3 1 9 1 1 0 0 0 0 3
1 8 15 7 8 0 0 0 0 0 0 4
9 5 7 3 1 0 0 0 0 4 0 1
11 4 3 3 0 0 0 4 0 4 0 0
0 3 3 0 0 1 0 c 1 0 4 0
1 0 7 4 0 0 0 5 1 0 0 1
5 0 4 0 0 3 7 7 3 0 3 3

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Trichophoxis epistomis

FIGURE 85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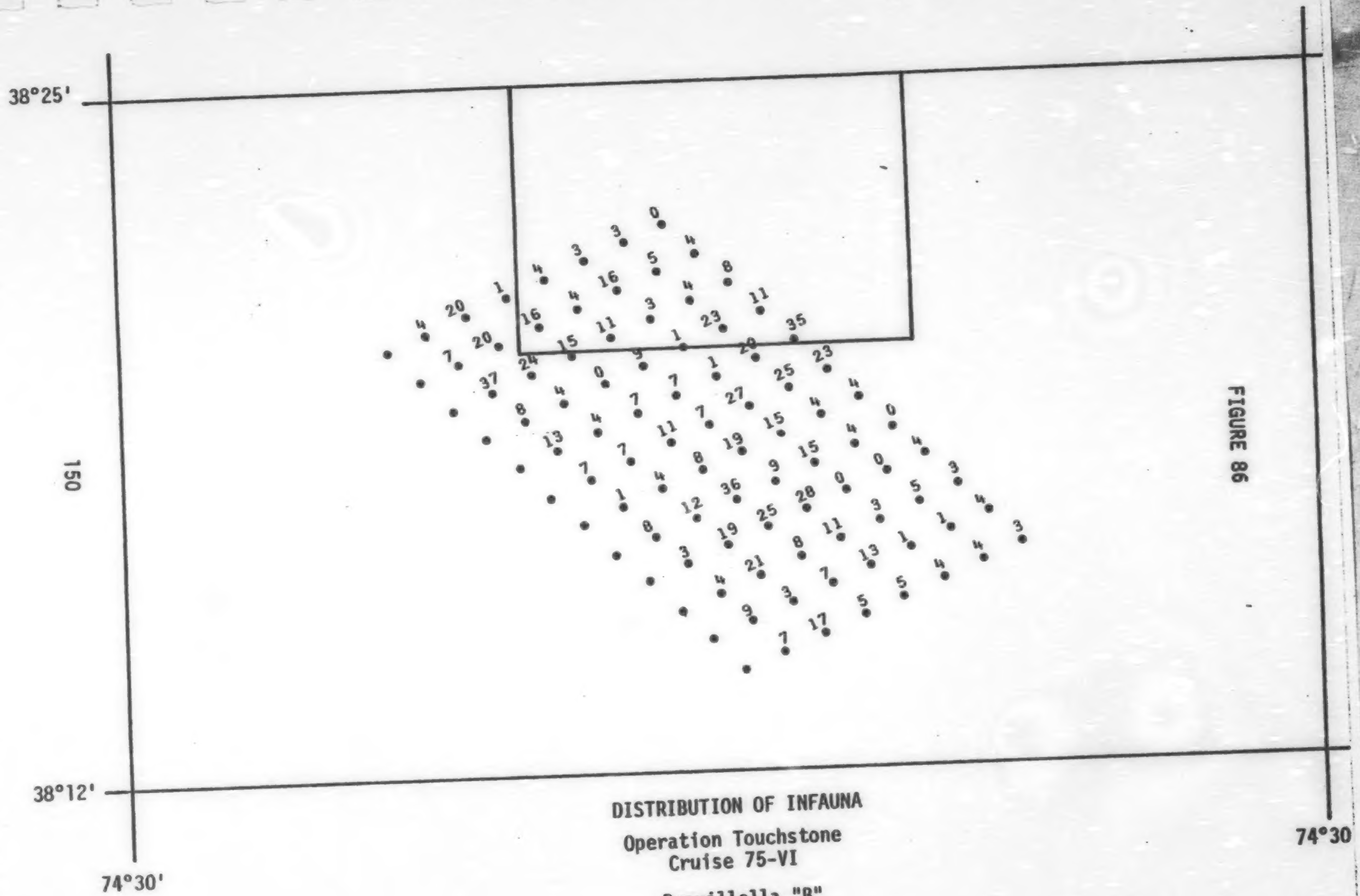
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Ampelisca vadorum

FIGURE 86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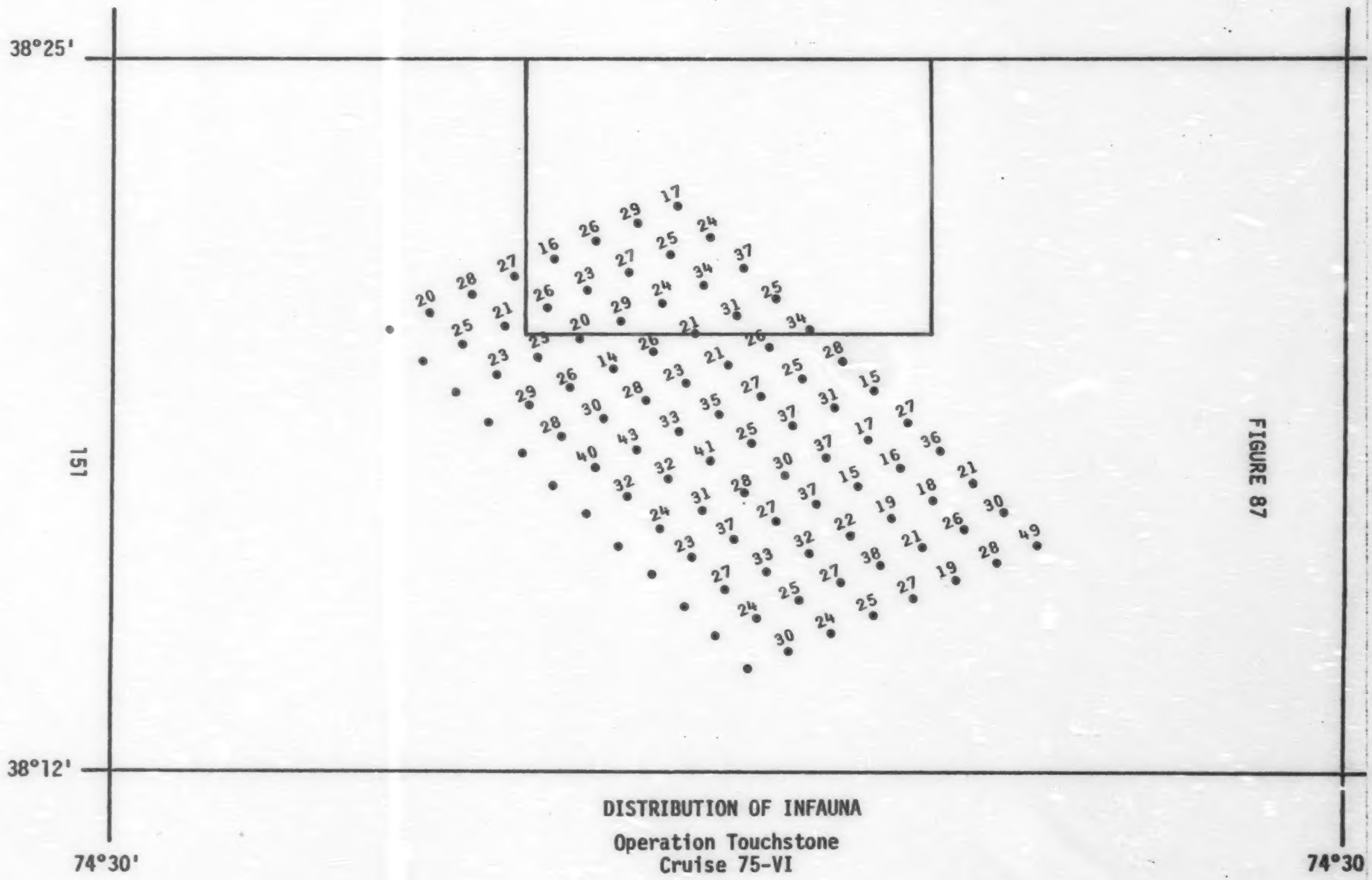
38°12'
74°30'
74°30
150
0 4 8 11 35 23 4 0 4 3 4 3
3 5 4 23 20 25 4 4 0 5 1 4
3 16 3 1 1 27 15 15 0 3 1 4
4 4 11 9 7 7 19 9 28 11 13 5
1 16 15 0 7 11 8 36 25 8 7 5
20 20 24 4 4 7 4 12 19 21 3 17
4 7 37 8 13 7 1 8 3 4 9 7

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Praxillella "B"

FIGURE 87


38°25'
38°12'
74°30'
74°30
17
24
37
25
34
28
15
27
36
21
30
49
29
25
34
31
26
25
31
17
16
18
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28
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38
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26
20
14
28
33
41
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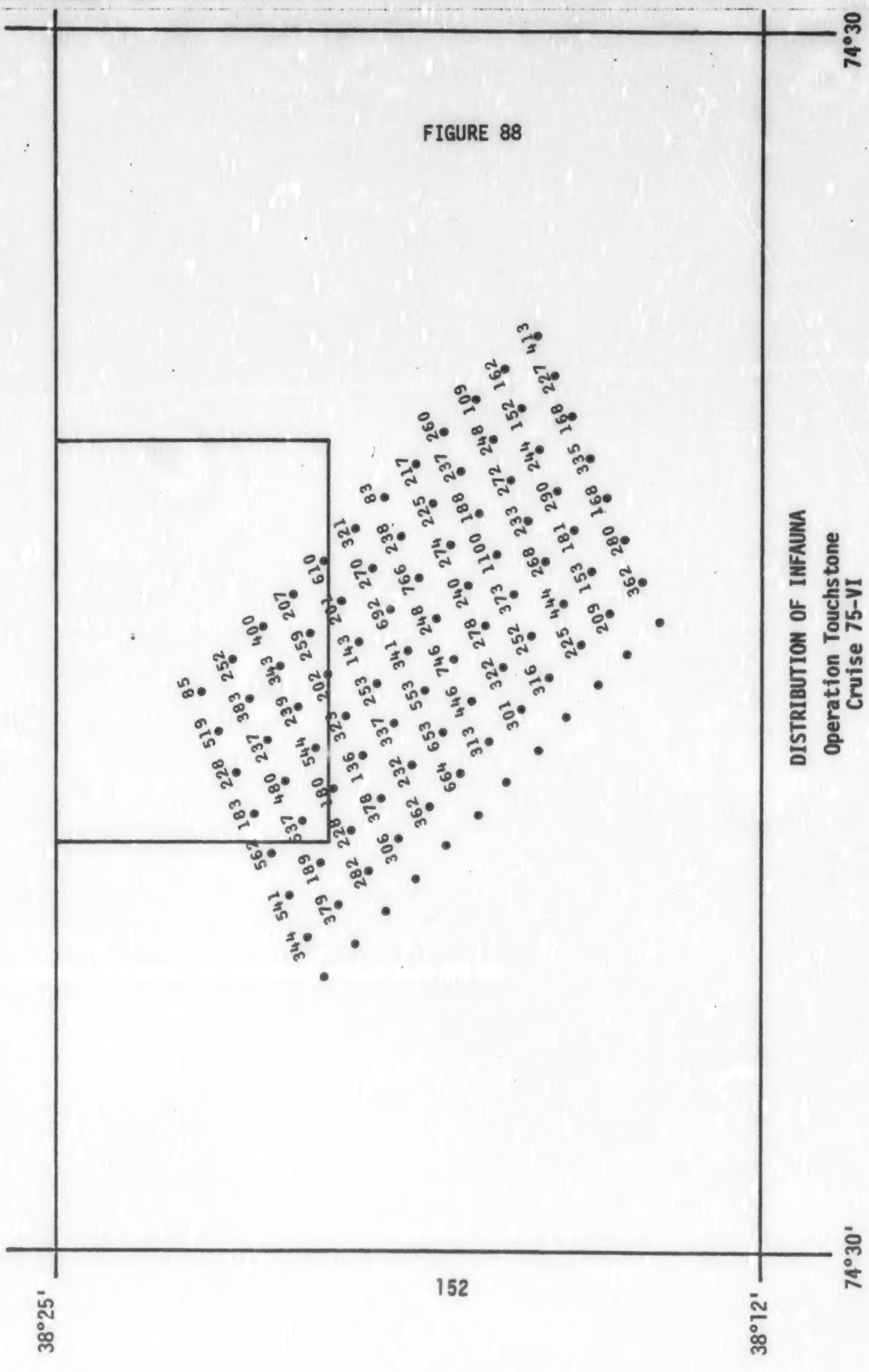
32
27
25
28
21
25
26
30
43
32
31
37
33
25
24
20
25
23
29
28
40
32
24
23
27
24
30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Number of Species

FIGURE 88



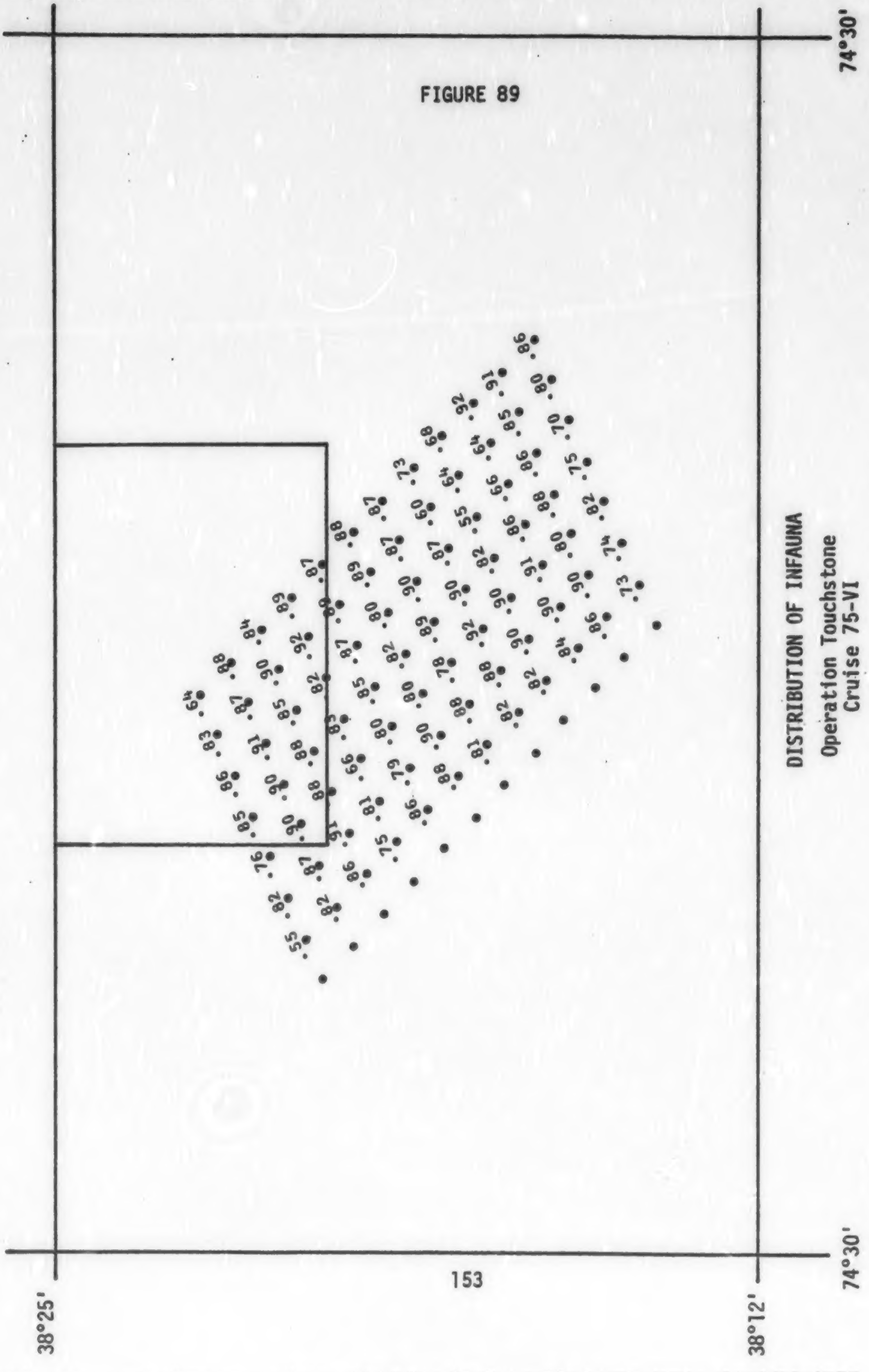
74°30
74°30'
38°25'
38°12'
85
252
400
207
610
321
83
217
260
109
162
413
519
383
343
259
201
270
238
225
237
248
152
227
228
237
239
202
143
692
766
274
188
272
244
168
183
480
544
323
253
341
248
240
100
233
290
335
562
537
180
136
337
553
746
278
373
268
181
161
541
189
228
378
232
653
446
322
252
444
153
280
344
379
282
306
362
664
313
301
316
225
209
362

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Number of Individuals

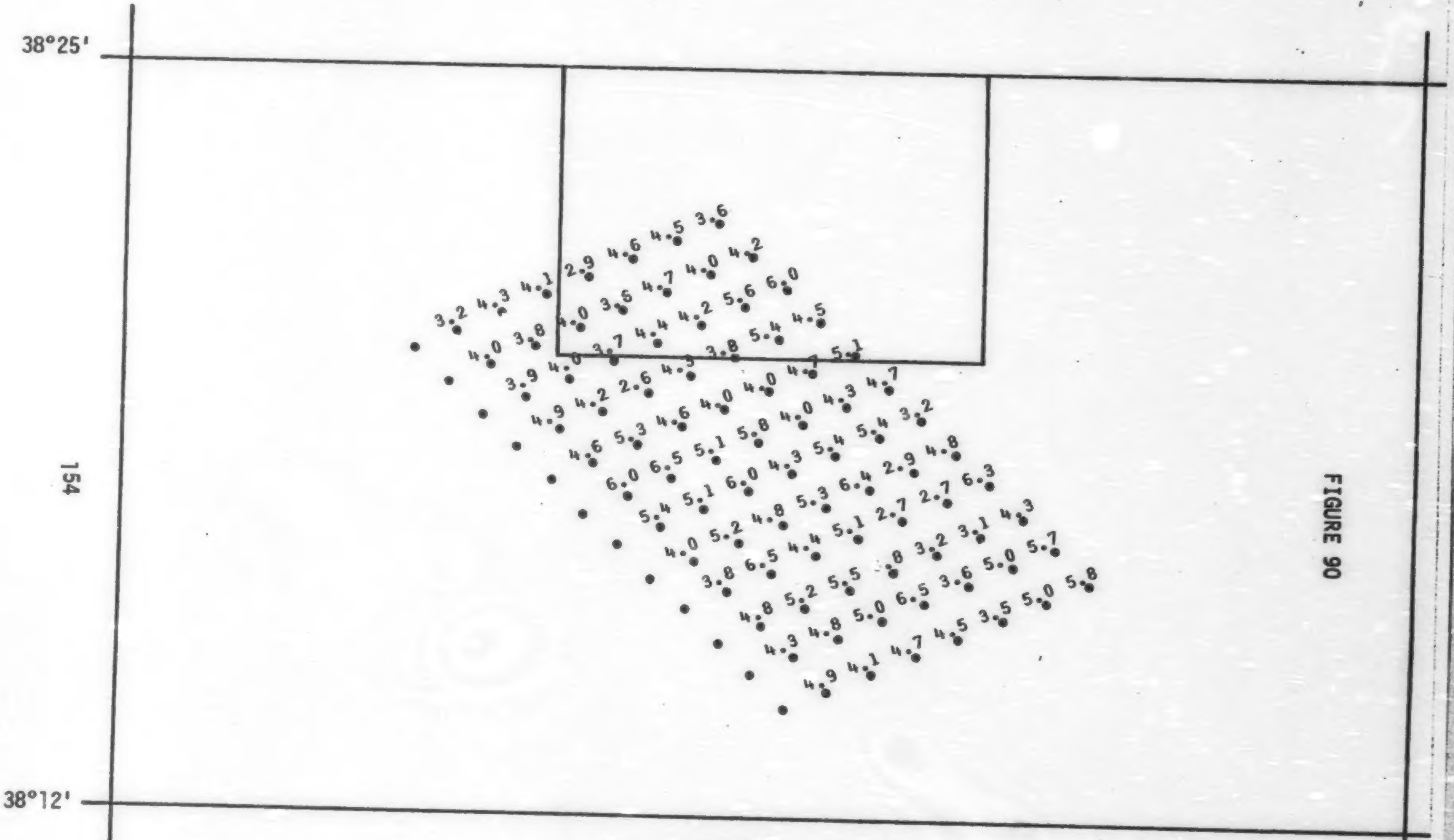
FIGURE 89


74°30'
74°30'
38°25'
38°12'

DISTRIBUTION OF INFAUNA
Operation Touchstone
Cruise 75-VI

Simpson's Index

FIGURE 90


38°25'
38°12'
3.2
4.3
4.1
2.9
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4.5
3.6
4.0
3.8
4.0
3.6
4.7
4.0
4.2
3.9
4.0
3.7
4.4
4.2
5.6
6.0
4.9
4.2
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5.1
5.8
4.0
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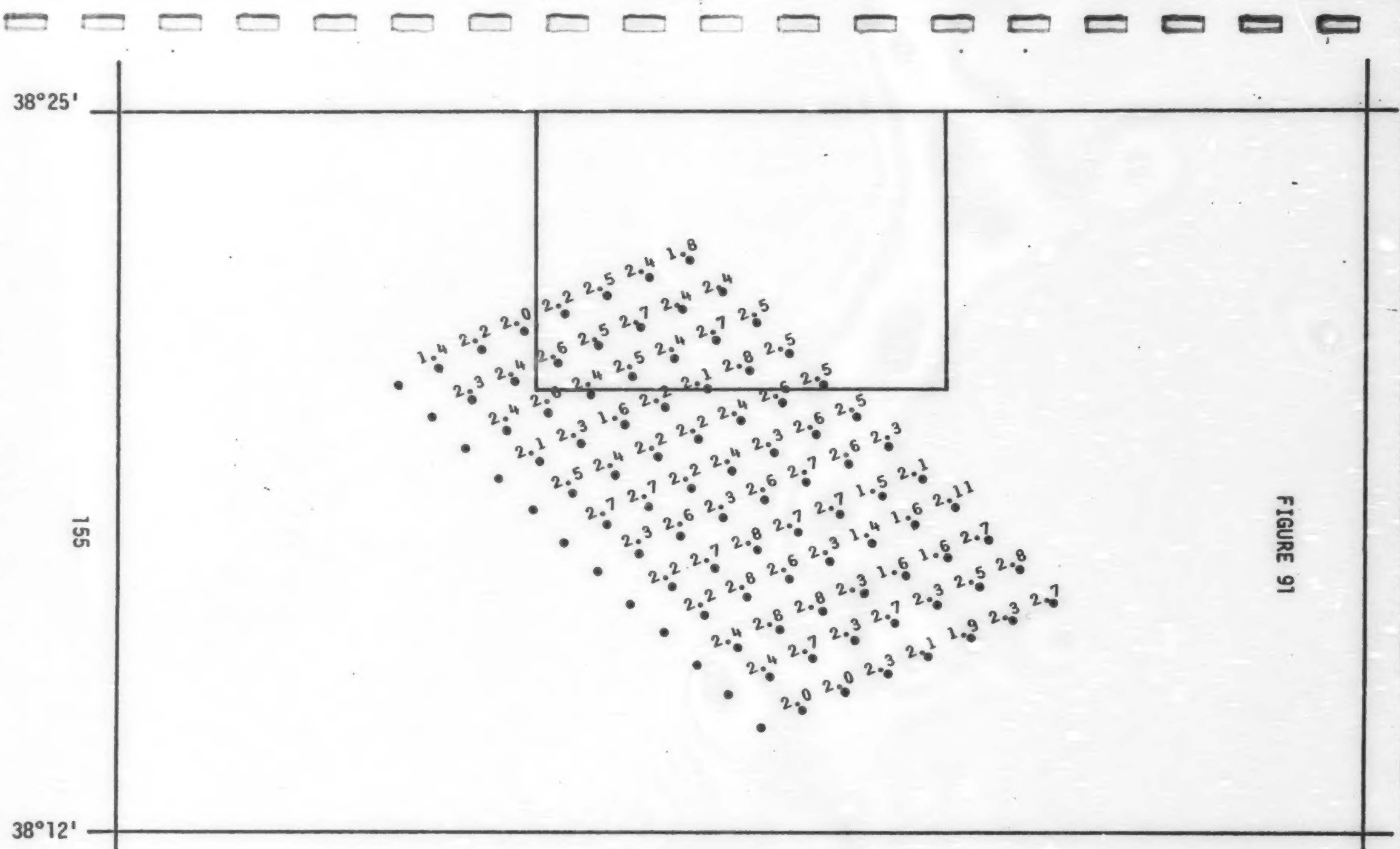
4.7
5.4
5.1
6.0
4.3
5.4
5.4
3.2
4.0
5.2
4.8
5.3
6.4
2.9
4.8
3.8
6.5
4.4
5.1
2.7
2.7
6.3
4.8
5.2
5.5
.8
3.2
3.1
4.3
4.3
4.8
5.0
6.5
3.6
5.0
5.7
4.9
4.1
4.7
4.5
3.5
5.0
5.8
74°30'
74°30

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Species Richness

FIGURE 91


38°25'
38°12'
74°30'
74°30'
1.4 2.2 2.0 2.2 2.5 2.4 1.8
2.3 2.4 2.6 2.5 2.7 2.4 2.4
2.4 2.0 2.4 2.5 2.4 2.7 2.5
2.1 2.3 1.6 2.2 2.1 2.8 2.5
2.5 2.4 2.2 2.2 2.4 2.6 2.5
2.7 2.7 2.2 2.4 2.3 2.6 2.5
2.3 2.6 2.3 2.6 2.7 2.6 2.3
2.2 2.7 2.8 2.7 2.7 1.5 2.1
2.2 2.8 2.6 2.3 1.4 1.6 2.11
2.4 2.8 2.8 2.3 1.6 1.6 2.7
2.4 2.7 2.3 2.7 2.3 2.5 2.8
2.0 2.0 2.3 2.1 1.9 2.3 2.7

DISTRIBUTION OF INFAUNA

Operation Touchstone
Cruise 75-VI

Shannon-Weaver Index

DISEASES OF MARINE ORGANISMS

Visible necrotic conditions or abnormalities or marine organisms have been described from known polluted areas, including the New York Bight. It has been a function in the cruise plans of the Region III monitoring expeditions to note abnormalities, lesions, growth, deformities, etc. In the wide area coverage, no obvious aberrancies were noted.

In the February 1977 cruise, while sampling with the rocking chair dredge in the intensive grid, adjacent and immediately south of the sewage sludge site, a live rock crab, Cancer irroratus, was noted with obvious lesions (Figure 92). As this sampling was for collection for other parameters further investigations were not accomplished on that cruise. More detailed collections in the intensive survey area are planned, based on this observation.

Macroscopic observations are obviously but a gross index of organic or infectious diseases. Samples of Arctica have regularly been collected, preserved and archived for histopathological determinations at the EPA National Marine Water Quality Laboratory, Narragansett, Rhode Island.

FIGURE 92

Cancer irroratus with Lesions

BACTERIOLOGY

Operation Hotspot - Cruise 76-II
August 1976

M. L. O'Malley

During Operation Hotspot, August 1976, 32 sediment samples and 3 shellfish samples were analyzed for total coliforms and fecal coliforms. All stations sampled were within the intensive sampling grid. (Figure 54). Sediments were subsampled from an undisturbed Smith-McIntyre bottom grab using a flame-sterilized 2.7 ml cylindrical scoop. This was introduced into a French square containing 100 ml of sterile distilled water and treated as a normal bacteriological sample. The French square was vigorously shaken and the sediment allowed to settle out over 2-3 minutes. The sample was split and run through both the total coliform and fecal coliform procedures as outlined in Standard Methods for the Examination of Water and Wastewater (1976). Incubation for coliforms was 24 hours at 35°C in a dry air incubator and at 44.5°C for fecal coliforms in a shaker water bath. Results were negative for both total coliforms and fecal coliforms for all sediments sampled as shown in Table 33.

A Fall River "rocking chair" dredge was deployed at Station 201 to obtain shellfish for bacteriological analyses. Two *Arctica islandica* clams and one horse mussel, *Modiolus modiolus* were tested. Each was shucked, weighed and ground in a sterile blender to facilitate handling. Standard total coliforms and fecal coliforms MPN's were estimated following procedures listed in "Standard Methods". A 3-tube, 3-dilution schema was employed using aliquots of 10.0, 1.0 and 0.1 ml of blended shellfish meat. MPN's for shellfish are also shown in Table 33. All shellfish tested contained both coliforms and fecal coliforms with the mussel, Modiolus, having the highest values for both.

Sediment samples showed no influence from municipal waste disposal, however the shellfish sampled contained coliforms and fecal coliforms. This indicated bacteriological studies should continue.

TABLE 33

BACTERIOLOGICAL DATA

Operation Hotspot - August 1976

GRID STATIONS

Station	Date	Time	Depth (Fathoms)	Sample	Coliform	F. Coliform
					plate cts./50 ml	
201	8/08/76	1615	25	Sediment	<1	<1
202		1645	27			
203		1110	27			
204		1552	28			
205		1710	29			
206		1140	29			
207		1535	27			
208		1730	29			
209		1042	27			
210		1203	30			
211		1515	29			
212		1750	30			
213		1014	25			
214		1224	25			
215		1447	34			
216		1810	32			
217		0953	25			
218		1303	32			
219		1423	33			
220		1830	32			
221		0920	32			
222		1333	33			
223		1338	33			
224		1847	35			
225		1845	35			
226		2014	37			
232		2218	25			
235		2128	26	Sediment	<1	<1
					MPN/100 gm	MPN/100 gm
201		2240	25	Arctica	3	<3
201		2240	25	Arctica	15	6.2
201	8/08/76	2240	25	Modiolus	29	29

BACTERIOLOGICAL ANALYSES

Operation Mogul - February 1977

Capt. Willard N. Adams
USPHS - Davisville, R. I.

The comments expressed in this section are the interpretations of bacteriological (coliform) analysis performed aboard ship during calm and rough seas and good and inclement weather conditions. The ship was not equipped to perform laboratory work, which required modifications of existing ship compartments and temporary laboratory installations. The ship's helicopter shack was used as an incubator room, which required an electric heater to maintain ambient temperature for the desired incubator operation during Operation Mogul. Temporary 4 x 6 x 8 ft. laboratory shacks were lashed to the railing of the ALERT. It was necessary to keep an electric heater operating in the temporary lab shacks to keep membrane filter (MF) apparatus (tubing) from freezing. Thirty-five mm slides of facilities and operations are available at North East Technical Services.

The results of coliform analysis of bottom waters, sediments and mahogany clam (*Arctica islandica*) samples are presented in Table 34 Figure 93 represents a flow diagram of the coliform analysis methodology employed aboard ship. These methods generally follow APHA *Recommended Procedures for the Examination of Sea Water and Shellfish*, 4th edition, 1970. However, some procedures were difficult to follow aboard ship such as gravametric procedures that require weighing a portion of sediment or shellfish homogenate. A special balance is required (not available during these studies) that will record weighings and compensate for ship movement. Volumetric measurements of shellfish homogenate were therefore made based on the equivalence of one ml to one gram of homogenate. Sediment measurements were made with a sterile wooden applicator, four approximate 2.5 g portions were estimated to represent a ten-gram amount of sediment. The temperature of the air incubators ranged between 35° to 37° C. rather than the 35±0.5°C recommended by APHA Recommended Procedures for the Examination of Sea Water and Shellfish, 4th edition, 1970. All other procedures, except those discussed above, for MPN and MF analysis were generally in agreement with the Recommended Procedures and Standard Methods.

The results expressed in Table 34 showed that of 20 water samples only 3 contained detectable MPN and MF coliform concentrations and only one sediment sample contained a detectable coliform MPN concentration. Water samples from Stations G-34, 205 and 207 had coliform MF concentrations of 0.6/100 ml, 1/100 ml and 0.2/100 ml respectively. The sediment coliform MPN concentration at Station 207 was 22/100 g.

Table 34 also shows that speciation of coliform bacteria isolated from water and sediment samples were not fecal coliforms. *Escherichia coli* was not isolated in these samples, but rather secondary coliforms such as *Enterobacter*, *Citrobacter* and *Pseudomonas* which are perhaps more resistant to the the marine environment than *E. coli*.

The significance of these results *suggest* that even though the coliform isolates are not specifically associated with fecal contamination they are associated with a heterotrophic terrestrial environment and are present in sewage. They are foreign to marine waters especially at the ocean depths salinity and temperature from which these samples were obtained.

Table 34 also shows the clams, Arctica islandica, to have a relatively higher concentration of coliforms than was indicated by water or sediment samples. Of the seven clam samples examined the MPN coliform count ranged from 36/100 g to 2400/100 g, and the fecal coliforms from 36 to 73 per 100 grams.

Speciation of the coliform isolated from clam samples, with the exception of Station 17-1, were not E. coli. Enterobacter, Klebsiella and Pseudomonas genera were isolated and identified from clam homogenates. The increased concentrations of these coliforms in the clams is probably caused by the filter-feeding habits of clams. A clam sample from Station 17-1 had an MPN concentration for coliform and fecal coliform of 9 /100 g, which was speciated to be E. coli. indicating a potential for more recent sewage deposition at this station.

The bacteriological results from Operation Mogul suggest that the count levels of secondary coliform indicator bacteria obtained from clam samples indicate concentration of these bacteria in the filter-feeding clams. Also speciation of coliforms isolated and identified from clam, sediment and water samples suggests that they are probably coming from sewage dumping. Additional studies in surrounding ocean areas out of the disposal site are required to establish background information presently lacking on the concentrations and speciation of bacteria present in the clams, sediment and water.

TABLE 34

BACTERIOLOGICAL DATA

OPERATION MOGUL
February 1977

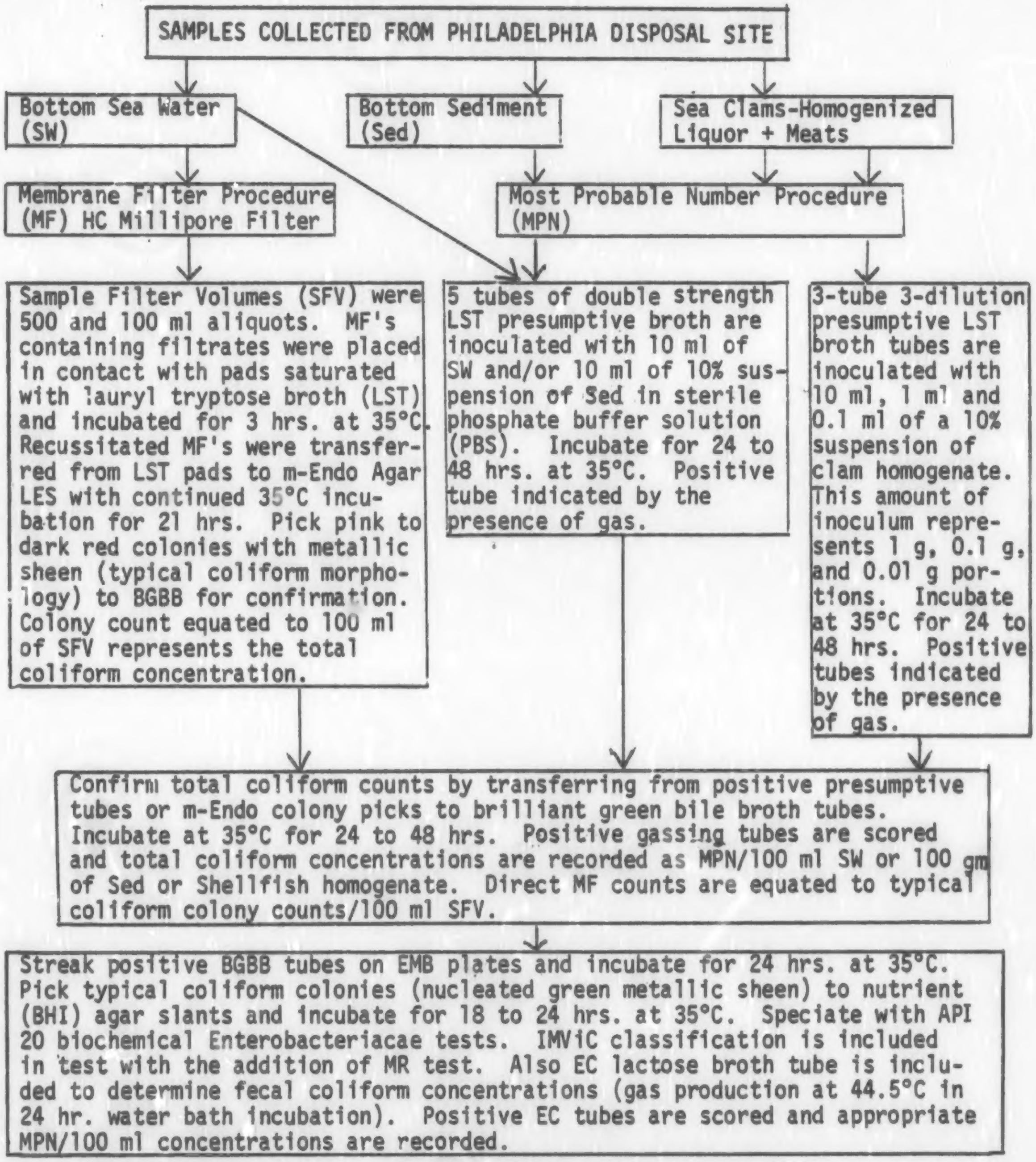
Station	Sample	MPN Total Coliforms/ 100 ml	MF Total Coliforms/ Count 100 ml	MPN Fecal Coliforms/ 100 ml	API Speciation	Date
32	Sediment	<22				2/16/77
G-34	Water	<2.2	0.6→	<1	Ent. agglomerams 4 ea	2/17
G-34	Sed.	<22				"
24-1	Clam	36		<36	Kl. pneumoniae Ent. aerogenes	" "
8	Clam	2400		73	Ent. cloacae - 3 ea Kl. pneumoniae - 4 ea	"
8	Sed.	<22				"
8	Water	<2.2	<1			"
17-1	Clam	91		91	E. coli - 2 ea	"
234	Sed.	<22				"
234	Water	<2.2	<1			"
201	Sed.	<22				"
201	Water	<2.2	<1			"
236	Sed.	<22				"
236	Water	<2.2	<1			"
205	Sed.	<22				"
205	Water	<2.2	<1	1	C. freundii	"
203	Sed.	<22				"
203	Water	<2.2	<1			2/18
207	Sed.	22/<22		<22	Ps. maltophilia	"
207	Water	<2.2	0.2→	<1	Ent. Cloacae	"
227	Sed.	<22				"
227	Water	<2.2	<1			"
238	Sed.	<22				"
238	Water	<2.2	<1			"
240	Sed.	<22				"
240	Water	<5.7	<1			"

TABLE 34 (cont.)

Station	Sample	MPN Total Coliforms/ 100 ml	MF Total Coliforms Count 100 ml	MPN Fecal Coliforms 100 ml	API Speciation	Date
210	Sed.	<22				2/18/77
210	Water	<2.2	<1			"
212	Sed.	<22				"
212	Water	<2.2	<1			"
213	Sed.	<22				"
213	Water	<5.7	<1			"
215	Sed.	<22				"
215	Water	<5.7	<1			"
220	Sed.	<22				2/19/77
220	Water	<5.7	<1			"
221	Sed.	<22				"
221	Water	<5.7	<1			"
223	Sed.	<22				"
223	Water	<5.7	<1			"
225	Sed.	<22				"
225	Water	<5.7	<1			"
242	Sed.	<22				"
242	Water	<5.7	<1			"
218	Sed.	<22				"
218	Water	<5.7	<1			"
Grid #1 209 - 1 mile SW	Clam	230		36	Ent. cloacae - 2 ea	"
Grid #2 218 - 1 mi toward 215	Clam	36/<36		<36	Ps. aeruginosa	"
Grid #3 206 - 1 mi toward 203	Clam	2400		73	Kl. pneumoniae - 3 ea Ent. cloacae 2 ea Ent.aerogenes	"
Grid #4 237 - 1 mi toward 236	Clam	91		<36	Kl. pneumoniae Ent. aerogenes	"

FIGURE 93

FLOW DIAGRAM OF COLIFORM PROCEDURES EMPLOYED IN OPERATION MOGUL


SAMPLES COLLECTED FROM PHILADELPHIA DISPOSAL SITE
Bottom Sea Water (SW)
Bottom Sediment (Sed)
Sea Clams-Homogenized Liquor + Meats
Membrane Filter Procedure (MF) HC Millipore Filter
Most Probable Number Procedure (MPN)

Sample Filter Volumes (SFV) were 500 and 100 ml aliquots. MF's containing filtrates were placed in contact with pads saturated with lauryl tryptose broth (LST) and incubated for 3 hrs. at 35°C. Recussitated MF's were transferred from LST pads to m-Endo Agar LES with continued 35°C incubation for 21 hrs. Pick pink to dark red colonies with metallic sheen (typical coliform morphology) to BGBB for confirmation. Colony count equated to 100 ml of SFV represents the total coliform concentration.

5 tubes of double strength LST presumptive broth are inoculated with 10 ml of SW and/or 10 ml of 10% suspension of Sed in sterile phosphate buffer solution (PBS). Incubate for 24 to 48 hrs. at 35°C. Positive tube indicated by the presence of gas.

3-tube 3-dilution presumptive LST broth tubes are inoculated with 10 ml, 1 ml and 0.1 ml of a 10% suspension of clam homogenate. This amount of inoculum represents 1 g, 0.1 g, and 0.01 g portions. Incubate at 35°C for 24 to 48 hrs. Positive tubes indicated by the presence of gas.

Confirm total coliform counts by transferring from positive presumptive tubes or m-Endo colony picks to brilliant green bile broth tubes. Incubate at 35°C for 24 to 48 hrs. Positive gassing tubes are scored and total coliform concentrations are recorded as MPN/100 ml SW or 100 gm of Sed or Shellfish homogenate. Direct MF counts are equated to typical coliform colony counts/100 ml SFV.

Streak positive BGBB tubes on EMB plates and incubate for 24 hrs. at 35°C. Pick typical coliform colonies (nucleated green metallic sheen) to nutrient (BHI) agar slants and incubate for 18 to 24 hrs. at 35°C. Speciate with API 20 biochemical Enterobacteriacae tests. IMViC classification is included in test with the addition of MR test. Also EC lactose broth tube is included to determine fecal coliform concentrations (gas production at 44.5°C in 24 hr. water bath incubation). Positive EC tubes are scored and appropriate MPN/100 ml concentrations are recorded.

Information available: Total and Fecal Coliform concentrations by MF and MPN methods in parallel.
Speciation of coliforms in the Enterobacteriacae family.
IMViC classification.

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